Overview of 1998 Pesticide Sales in Alberta

June 2000

Municipal Program Development Branch
Environmental Sciences Division
Environmental Service

Pub. No.: T/535
ISBN: 0-7785-1180-4 (Printed edition)
0-7785-1181-2 (On-line edition)

Website Address: www.gov.ab.ca/env/protenf/pesticide

ACKNOWLEDGEMENTS

The assistance and input of the following people was greatly appreciated during the preparation and compilation of this report:

Janet Mclean, Neil Wandler, Anne-Marie Anderson, Doreen LeClair, Jim Ames and Carol Thurston of Alberta Environment;

Sandra Cooke, Walter Yarish, Phil Thomas and David Neilson of Alberta Agriculture, Food and Rural Development.

More information regarding the "1998 Overview of Pesticide Sales in Alberta" may be obtained by contacting:

Municipal Program Development Branch
Environmental Sciences Division
Environmental Service
Alberta Environment
4th Floor 9820 – 106 Street
Edmonton, Alberta T5K 2J6
Phone: (780) 427-9911

100-07340/

Overview of 1998 Pesticide Sales in Alberta

Gary Byrtus
Environmental Sciences Division
Alberta Environment
June 2000

EXECUTIVE SUMMARY

Alberta Environment undertook the collection, consolidation and analysis of pesticide sales data from pesticide vendors in Alberta in 1998. The objective was to document the volume and types of pesticides sold in Alberta, and to prepare a general overview of the sales data in relation to sectors of use, types of use, chemical groupings, as well as geographic breakdowns by river basin, ecoregion, municipality and departmental regions. This project was a follow-up to a pesticide sales survey that last occurred in 1993. The overview follows the chemical grouping format used by Quebec in their reporting on pesticide sales in their province, and with the proposed National Pesticide Sales Database.

Pesticide sales data was requested from registered pesticide vendors and wholesalers in Alberta in early 1999, under the authority of the Environmental Protection and Enhancement Act and supporting regulations. Approximately 97% compliance with the sales data request was obtained. Sales data received was digitized or reformatted to a common database format. Six additional databases were constructed to assist with sorting and categorizing the sales records by chemical or geographic groups. The databases were brought into Access, where they were linked and various output was obtained.

In 1998, a total of 9 300 497 kg of pesticide active ingredient (ai) was sold in, or shipped into, Alberta. Pesticides sold into the Agriculture sector accounted for 95.8% of all pesticides sold, with the Commercial/Industrial sector accounting for 3.3% of sales, and the Domestic sector accounting for 0.8% of sales. The types of pesticides sold were predominantly herbicides, at 76.7%. Adjuvants and surfactants made up the next largest category at 14.25%. Insecticides made up 5.4% of sales, while fungicides made up 3.6% of sales.

Of the chemical groups, the Phosphonic Acids, Phosphinic Acids group was the largest at 29.9% of overall sales. However, in the Domestic sector, the Phenoxy Acids group dominated with 44.8% of pesticide active ingredient sold.

Looking at geographic distributions, the Oldman River basin had the highest overall sales at 20.3%, followed by the Red Deer River basin at 18.8% and the North Saskatchewan River basin at 15.8%. Relative use intensities (based upon gross drainage area) were highest for the Oldman River basin, at 0.69 kg ai/ha.

When pesticide sales were sorted by ecoregion, the Aspen Parkland had the highest amount of sales, at 33%, followed by the Moist Mixed Grassland at 22.6%. This is partly attributed to the large size of the Aspen Parkland ecoregion in Alberta, and the large amount of agricultural land it encompasses.

Geo-administrative regions were also summarized, for use in program planning. The municipalities with the highest sales were the County of Lethbridge and the MD of Taber, at over 500,000 kg of active ingredient. Based upon their cropped acreage, pesticide use intensities of over 2.5 kg ai/ha were estimated.

This compares to an overall provincial estimated pesticide use intensity (based upon cultivated land acreage) of 0.79 kg ai/ha. Other municipalities with over 300,000 kg ai of pesticide sales were the Counties of Red Deer, Vulcan, Vermilion River and Wheatland. Estimated pesticide use intensities for these municipalities ranged from 1.20 to 1.36 kg ai/ha. These municipalities may also serve as regional supply centres, so the use intensity estimates may be an overestimation.

Pesticide sales were also sorted by Alberta Environment regions. The Parkland and Prairie regions were the highest, at over 2.5 M kg ai each. Agricultural pesticide sales were also sorted by Alberta Agriculture, Food and Rural Development regions. Highest sales were in the Southern region at over 3.2 M kg of active ingredient, followed by the Northern region at 2.7 M kg ai.

The overview of pesticide sales data for Alberta has provided Alberta Environment and other agencies with the background data to enable comparisons to other regions, and to assist in ensuring that Alberta Environment has the appropriate regulatory framework in place for pesticides. The data will also be useful in identifying monitoring priorities for ongoing and upcoming monitoring programs.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i

1.0 Introduction 1

2.0 Methods 3

2.1 Sales Data *3*
2.1.1 Sales Data Collection 3
2.1.2 Sales Data Assumptions 3
2.1.3 Sales Data Limitations 4

2.2 Pesticide Databases *6*

2.3 Geographic Databases *6*

2.4 Data Processing *6*

2.5 Data Breakdown *7*
2.5.1 Type of Use 7
2.5.2 Chemical Group 8
2.5.3 Sector of Use 9
2.5.4 Resistance Groupings 9
2.5.5 Geographic Units 10
2.5.5.1 Drainage Basins 10
2.5.5.2 Ecoregions 10
2.5.5.3 Municipalities 11
2.5.5.4 Irrigation Districts 11

3.0 Results 11

3.1 Type of Use *12*

3.2 Chemical Group *13*

3.3 Sector of Use *13*

3.4 Herbicide Resistance Groups *18*

3.5 Geographic Distributions *20*
3.5.1 Drainage Basin 20
3.5.2 Pesticide Sales by Ecoregion 22
3.5.3 Pesticide Sales by Municipality, AENV and AAFRD Regions 23
3.5.4 Pesticide Sales by Irrigation District 26

4.0 Discussion 34

4.1. Use Intensity *34*

4.2 Pesticide Sales Data for Quebec *35*

4.3 Herbicide Tolerant Canola *36*

4.4 Herbicide Resistance *37*

4.5 Drainage *38*

5.0 Conclusions 39

6.0 References 40

Appendix 1. Chemical Groups and Active Ingredients 42

Appendix 2. Herbicide Groups Based on Sites of Action for Resistance Management 56

TABLES

Table 1. Pesticide Sales by Type of Use 12

Table 2. Summary of Pesticide Sales by Chemical Group (all sectors) 13

Table 3. Pesticide Sales by Sector 14

Table 4. Summary of Agricultural Pesticide Sales by Chemical Group 15

Table 5. Summary of Domestic Pesticide Sales by Chemical Group 17

Table 6. Agricultural Herbicide Sales by Resistance Grouping 18

Table 7. Pesticide Sales by River Basin – Area 20

Table 8. Pesticide Sales by River Basin – Flow 21

Table 9. Pesticide Sales by Ecoregion 23

Table 10. Crop Groups Grown in High Pesticide Sales Municipalities (hectares), With Agricultural Sales (kg ai) and Use Intensity (kg ai/ha) 24

Table 11. Pesticide Sales by Municipality 24

Table 12. Pesticide Sales by AENV Region 25

Table 13. Agricultural Pesticide Sales by AAFRD Region 26

Table 14. Pesticide Sales by Irrigation District 26

FIGURES

Figure 1. Agriculture Sector – Type of Use 14

Figure 2. Domestic Sector – Type of Use 16

Figure 3. Commercial/Industrial Sector – Type of Use 18

Figure 4. Total Pesticide Sales By River Basin ('000 kg ai) - 1998 28

Figure 5. Estimated Pesticide Use Intensity by River Basin (kg/ha) - 1998 29

Figure 6. Total Pesticide Sales by EcoRegion ('000 kg ai) - 1998 30

Figure 7. Total Pesticide Sales by Municipality ('000 kg ai) - 1998 31

Figure 8. Alberta Government Regions 32

Figure 9. Irrigation Districts in Alberta 33

1.0 Introduction

Pesticide use statistics are becoming a valuable piece of information worldwide for regulatory and monitoring agencies in order to enable more efficient use of resources in the regulation of pesticides, and in the monitoring of pesticides in various environmental matrices. The OECD (Organization for Economic Co-operation and Development) has reported that most of its member countries collect pesticide sales or use information for various purposes (OECD, 1999). Because detailed pesticide use information is extremely expensive to assemble, most jurisdictions use pesticide sales information as surrogate data. Canada is one of two countries that responded to the OECD survey indicating that it does not collect pesticide sales data (the other was the Slovak Republic). However, the Pest Management Regulatory Agency (PMRA) is currently in the development phase of a nationwide pesticide sales survey. PMRA data will only provide total provincial sales, which is not sufficient to meet our needs, but will be important in helping to ensure accurate accounting. The state of California, however, collects detailed pesticide use data by active ingredient, crop and acreage, primarily for their agricultural sector (California Department of Pesticide Regulation, 1999).

Alberta Environment collected pesticide sales information for the period 1988-1993 from major line companies (Cotton and Byrtus, 1995), and used this information to assist in the development of a major surface water monitoring program conducted from 1995-1996 (CAESA, 1998). Although the data was limited to agricultural product sales, and limited to approximately 50-60% of the total agricultural sales, it did provide trend information on certain products. It also provided a geographic perspective on pesticide sales, which was important for determining monitoring locations. Subsequent to that report, data on 1993 domestic pesticide sales was also obtained from major distributors and retailers, and this unpublished information was used in the development of a factsheet on pesticide use in Alberta (AENV, 1998a).

Alberta Environment undertook a five-year update for 1998 pesticide sales, encompassing a more comprehensive data collection process. Alberta Environment, under the Environmental Protection and Enhancement Act and supporting regulations, has the authority to request pesticide sales records from wholesale and retail vendors to enable enforcement actions, as well as for the consolidation of data to enable efficient management of pesticides in Alberta. For the 1998 sales project, vendors of agricultural, domestic, livestock, commercial and industrial, and structural pest control products were surveyed. The data received was inputted, and pesticide sales were

broken down by: (1) sector of use; (2) chemical group; (3) resistance groupings; and (4) geographic distribution by either drainage basin, ecoregion, municipality or irrigation district. As this data is more comprehensive than that collected in 1993, direct comparison to the 1993 data is not possible.

The data in this overview will assist Alberta Environment and other provincial and federal agencies in comparisons of pesticide sales/usage information. It will help to identify monitoring priorities for ongoing and upcoming monitoring programs. It will also assist Alberta Environment in ensuring that the appropriate regulatory framework is in place for the pesticides in current use in Alberta.

The specific objectives of this project were:

1. To assemble pesticide sales records representing pesticide use for the calendar year 1998.
2. To categorize pesticide sales by chemical group, sector of use, and geographic distribution

2.0 Methods

2.1 Sales Data

2.1.1 Sales Data Collection

Alberta Environment maintains a registry of pesticide vendors that retail restricted and commercial registered pesticide products, as well as wholesale distributors of domestic class products. This registry is maintained as a component of the Alberta Environment Environmental Management System, which tracks many of the approvals and registrations issued by Alberta Environment that fall under the Environmental Protection and Enhancement Act. Under the authority of this Act and its supporting regulations, AENV can request pesticide sales records from vendors. In December of 1998, a preliminary outline of the data collection process was sent to all registered vendors in Alberta, along with a copy of the factsheet "Pesticide Use in Alberta" (AENV, 1998a). In early February of 1999, the primary data request letter was sent out to all registered vendors, or head offices of registered vendors (254 letters). Data was received from the vendors in hard copy and digital formats. Non-compliers were sent a formal request letter from regional directors of AENV in Nov/Dec of 1999. Overall compliance at the time of this writing was 97%. This process also enabled Alberta Environment to update its vendor registry, and identify those vendors who were no longer involved in selling pesticides.

Hard copy records were manually inputted into a standardized database file, while digital files were converted to the standardized database (dBASE V) format, which consisted of vendor approval number, product registration number (PCP No.), quantity sold in litres or kilograms and sector of use. Individual vendor data files were consolidated into a single sales database, which contains just over 69,000 records.

2.1.2 Sales Data Assumptions

There are some major assumptions involved in using pesticide sales data as a surrogate for pesticide use. The primary one is that products sold are used in the year of sale. While this may be the case for most agricultural products, this may not be the case with domestic products. Domestic products are usually shipped by case lots, so unless point of sale information was obtained, only case lot quantities are recorded. Also, records from wholesale distributors (agricultural and domestic) rarely account for inventory carryover (winter period), unless product is returned to the distributor. Some data comparison was done for a major agricultural distributor and some of the retail outlets that they had shipped to. It was quite apparent from comparing the

records that some product sold in any one year comes out of overwintering inventory, and some product that is unsold goes into overwintering inventory. Therefore, depending upon wholesale records alone does not guarantee an accurate picture of pesticide sales or use.

2.1.3 Sales Data Limitations

Sector Representation

The data from vendors that are primarily agricultural suppliers may have contained sales to the landscape industry, the industrial sector, municipal governments, golf courses and other non-agricultural sectors, which were not identified. As a result, the agricultural sector may be over-represented, while the other sectors may be under-represented.

Treated Seed

Sales of fungicide and insecticide treated seed was not captured in this survey. However, sales of seed treatment compounds to farmers for on-farm treatment and to seed cleaning plants were covered. Most of the commercial seed treatment facilities that treat registered and specialty seeds (e.g., Roundup Ready canola, Liberty Link canola) would have had their pesticide usage covered if they had purchased their seed treatment products in Alberta. However, treated seed from out of province suppliers would not have been covered. The collection of treated seed sales data was beyond the scope of this project, particularly as seed distribution is often done by seed vendors or seed divisions rather than agricultural chemical divisions of the line companies. Estimates of herbicide tolerant canola planted in 1998 was approximately 61% of the 1 760 445 hectares planted to canola in Alberta, based upon insured seeded acres (Thomas 2000). Virtually all herbicide tolerant canola is treated with fungicide/insecticide (carbathiin/lindane mainly)(Thomas, 2000).

Geographic Resolution

Since 1993, the major agricultural input suppliers in Western Canada have been consolidating their operations, through closure of grain elevators and opening of farm supply centres, which are generally Crop Protection Institute (CPI)-audited warehouses. This has resulted in fewer sales outlets throughout Alberta, with a resulting loss of geographic discrimination in regards to sales information. For 1998, this has been partially compensated for by the inclusion of independent agricultural input suppliers, which were not included in the 1988-1993 sales survey (Cotton and Byrtus, 1995).

Vendor List

The vendors surveyed were based upon the 1998 Pesticide Vendor Registrations (Blue List) that Alberta Environment publishes each year (AENV, 1998b). Because certain sectors are exempt from requiring a vendor registration, this survey does not address all pesticide sales in Alberta. For example, many of the livestock products have been exempted from vendor registration requirements, and although the Blue List does show a number of livestock vendors, this is because they also retail strychnine-based rodenticides, for which a vendor registration is required. Therefore, the livestock product information is not complete. Also, disinfectants, anti-microbial products and wood preservatives are exempted from requiring a vendor registration, so there is virtually no sales data on those products.

Domestic Products

The sales records obtained from the agricultural and industrial sectors were often very accurate in terms of product sold, as they were obtained from the point of sale system for each outlet. Only one domestic distributor provided point of sale records, while most domestic records were based upon product shipped to various outlets (usually case lots) and not point of sale records. Because it is not known how much product came out of individual stores inventory in the spring, and went into inventory in the fall, it was assumed that the product shipped to the various domestic retail outlets in 1998 was sold in 1998.

In the domestic sector, pet care products sold in Alberta were not identified in this survey, nor were lawn and garden or household pesticides shipped into Alberta from small distributors elsewhere. Some miscellaneous household (indoor) pesticides were also missed in this survey, as they are classified as Schedule 4 products, which have been exempted from the provincial regulations as far as requiring wholesale vendor registrations, or retail dispenser certification.

Non-Specific Records

Some vendors (distributors/wholesalers) were unable to identify retail outlets for their shipments for a variety of reasons. These sales data were identified as "Alberta", and as a result, would not be included in any geographical breakdown. These records would, however, be included in chemical group summaries.

2.2 Pesticide Databases

In order to consolidate pesticide formulation sales information down to active ingredient and then to chemical group, two separate databases were also incorporated. The first of the pesticide databases was the pesticide Product database, which was obtained from the PMRA in early 1998, and updated with 1998 registrations as well as registrations under the Fertilizer Act for domestic fertilizer blends containing pesticides. This database has information required for this project on the product registration number, active ingredient, guarantee, as well as product name, registration status, etc. This database has 13,286 records. The second pesticide database was the Active database, which included active ingredient codes, active ingredient names, and to which chemical family, chemical group and resistance groupings were added. There is a total of 555 records in this database, however this includes disinfectants, antimicrobials and a few active ingredients that are no longer registered or sold in Canada.

2.3 Geographic Databases

Four databases were used to identify the geographic distribution of pesticide sales information. The primary database was the Vendor database, which included the vendor registration number, along with the vendor name and city, town, village or hamlet that the vendor was located in or nearest to. As a number of sales records were received for vendors that do not require vendor registrations in Alberta (primarily domestic retail vendors), dummy vendor numbers were also generated for these. Dummy vendor numbers were also generated for all municipalities in Alberta to enable geographic identification of minor vendors, or sales records to end users. Another major database was the City database, which lists all of the municipalities in Alberta. Associated with each municipality was the corresponding reference for rural municipality, drainage basin, ecodistrict and irrigation districts. Secondary databases included Drainage (which cross-referenced drainage basin and river basins), and Ecoregion (which cross-referenced ecodistrict and ecoregions – based upon information provided by Alberta Agriculture, Food and Rural Development).

2.4 Data Processing

The databases were imported into Microsoft Access for linking and querying. The databases were linked by related fields to calculate active ingredient values, and subsequent data groupings by chemical group, sector of use, and geographic distribution (see Cotton and Byrtus, 1995 for an example of how the calculations were done). Conversion of formulated product sales to kg of active ingredient (ai) is a common means of expressing pesticide sales/use in other jurisdictions

(Gregoire, 1997), although actual reporting is often based upon chemical group or by sector of use. This document will report pesticide use by chemical group in order to be consistent with data reported by the Province of Quebec (Gregoire, 1997; Gorse, 1999), and with the reporting format agreed upon by the National Pesticide Sales Database Working Group.

Assumptions were made with respect to pesticide formulations, such as the specific gravity of all pesticides being 1.0. Biological pesticides such as *Bacillus thuringiensis* formulations will be reported as units of mass sold (kg), based upon an assumption of 100% active ingredient. As biological pesticides are registered based upon toxicological units (e.g., BIU, AAU, ITU, etc) and not percentage active ingredient, they will be represented as total mass sold.

Products that contain more than one active ingredient were assigned an extension number to the PCP number for each of the active ingredients involved in both the sales and product databases. This enabled the use of the existing registration numbers with only a minor modification, and also enabled the software used for the data processing to accurately identify each component of a formulation. However, this resulted in additional records being added to the sales database to account for each active ingredient in a formulation (approximately 20,000 records).

2.5 Data Breakdown

In order to simplify the analysis of the data, consolidation of the data based upon type of use, chemical group and sector of use was undertaken.

2.5.1 Type of Use

Under the PCP Act, pesticides are classified into 39 product types (herbicides, insecticides, fungicides, etc) of products, which reflect their type of use. For the purpose of this document, the categories have been reduced to 6 primary types of use. All of the active ingredients identified in sales made in Alberta in 1998 are included in one of the types of use listed here. For those active ingredients that have multiple types of uses (such as thiram, which is a fungicide and a vertebrate repellent), the product is listed under its primary usage for Alberta.

- Herbicides and plant growth regulators
- Insecticides, acaracides, repellents,
- Fungicides
- Vertebrate control products and vertebrate repellents
- Adjuvants/surfactants
- Other: (Soil fumigants, wood preservatives, disinfectants, anti-microbials)

As the primary focus of this survey was on traditional pesticides, and not anti-microbial or disinfectant pesticides, sales data from industrial and domestic cleaning agents were not obtained or included, although these are also registered under the PCP Act. Adjuvants and surfactants are widely used in the agricultural industry in Alberta, so these records were included as a separate category.

2.5.2 Chemical Group

The chemical groupings (listed below) used for this overview are based primarily upon the groups established by the National Pesticide Sales Data Base, using an interim list dated February of 2000 (Appendix 1). This list is still under review, and could be subject to further changes. This list is derived from a variety of sources, with the main source being the list used by Quebec in their pesticide sales groupings (Gorse, 1999), although there are a number of minor differences in the chemical groups used here and by Quebec. Several of these groups contain more than one chemical family. For example, the Amides, Anilines group contains compounds from the anilides, amides and benzamides families.

Chemical Groupings Used In This Overview

- Alcohols
- Amides, Anilines
- Amino Acids
- Ammoniums, Quaternary
- Aryloxyphenoxyl Acids
- Azoles, Diazoles, Oxazoles, Thiazoles, Triazoles
- Bacillus thuringiensis species
- Benzimidazoles, Phenylpyrroles
- Benzonitriles, Nitriles
- Carbamates
- Carboxylic Acids
- Chlorophenols
- Chromenones
- Cyclohexanedione Oximes
- Diazines, Quinoxalines, Morpholines
- Dicarboximides, Oxathiin
- Dithiocarbamates
- Fatty Acids
- Halogenated Hydrocarbons
- Hydrocarbons
- Indanediones
- Inorganic Coppers
- Inorganic Zincs
- Inorganics, Other
- Microbials (Other than Bt)
- Miscellaneous (Non-classified)
- Nitro Derivatives
- Oils, Mineral and Vegetable
- Organic Acids
- Organochlorines
- Organometallics
- Organophosphorous
- Phenols
- Phenoxy Acids
- Phosphonic Acids, Phosphinic Acids
- Phthalic Acids
- Pyrethroids, Pyrethrins
- Pyridines
- Sulfonylureas, Uracils
- Thiocarbamates
- Triazines, Triazinones, Tetrazines
- Urea Derivatives

2.5.3 Sector of Use

The intent of categorizing the sales by sector of use was to attempt to differentiate between various sectors and their relative usage of pesticides in Alberta. Initially, it was thought that the sales could be differentiated by product and by the vendor. For products such as home and garden pesticides (Domestic sector), and products used on livestock (Livestock sector), this was relatively easy. However, the sales records indicated that several of the vendors who sell agricultural products primarily also sold herbicides that were primarily for turf, non-cropland, right of way (ROW) or landscape usage (Commercial/Industrial), and would not be used for agricultural production purposes, except perhaps for pasture renovation. These records were categorized as Commercial/Industrial.

Some products have multiple use locations such as agriculture, landscaping or ROW maintenance. As the end use for these products could not be distinguished, these purchases at agricultural vendors have been included under the Agricultural sector. The resulting breakdowns therefore, are simplified and may not accurately reflect actual usage in Alberta. Better delineation of this information may occur over the next five years, as AENV is undertaking industry sector surveys for certified applicators and registered services to estimate sector use.

The sectors of use used in this report include:

- Agricultural
- Domestic
- Commercial/Industrial (includes forestry, ROW, landscaping, golf courses, municipal)
- Livestock
- Structural.

2.5.4 Resistance Groupings

Herbicide resistance is a major issue in western Canada crop production, because of the widespread use of herbicides. In order to assist in identifying patterns in the use of products with known resistance in Alberta, each active ingredient was classified by its resistance grouping by site of action as outlined in PMRA Regulatory Directive DIR99-06 (PMRA, 1999). The herbicide resistance groupings in this document are based upon the Weed Science Society of America classification. There are 28 resistance groups identified for herbicide active ingredients currently registered in Canada. This document also classifies the insecticides and fungicides with

known resistance, although insecticide and fungicide resistance is not a major issue in Alberta at this time.

2.5.5 Geographic Units

2.5.5.1 Drainage Basins

There are 14 major drainage basins that are identified in Alberta. Within these drainage basins are numerous sub-basins, which define the watersheds of major tributaries. In order to assist the interpretation of pesticide monitoring data for Alberta, which is reported by major basin, and sometimes by sub-basin, identification of overall pesticide usage by drainage basin is required. All of the municipalities in the City database were identified as to their respective sub-basin. The major drainage basins in Alberta used for this report are:

- Athabasca River
- Battle River
- Beaver River
- Bow River
- Hay River
- Milk River
- North Saskatchewan River
- Oldman River
- Peace River
- Red Deer River
- Sounding Creek
- South Saskatchewan River

2.5.5.2 Ecoregions

There are ten major ecoregions in Alberta, which contain a total of 282 ecodistricts. To link pesticide sales to the various ecoregions in Alberta, each municipality in the City database was located to a specific ecodistrict, which was then linked to the respective ecoregion in the Ecoregion database. The detailed maps used to determine municipality location in relation to ecodistrict were obtained from AAFRD (1999a) and Strong and Thompson (1995). The ecoregions identify different ecological zones within Alberta, which are influenced by soil type, climate, physiography, water, fauna, land use, and vegetative cover (ESWG, 1995). The ecoregions of Alberta are:

- Aspen Parkland
- Athabasca Plain
- Fescue Grassland, Cypress Hills
- Mixed Boreal Upland
- Mixed Grassland
- Moist Mixed Grassland
- Northern Alberta Uplands
- Peace Lowland/Boreal Transition
- Subalpine and Alpine
- Western Alberta Uplands

2.5.5.3 Municipalities

There are 88 municipalities (rural municipalities, cities and national parks) in Alberta. Pesticide sales were allocated to the municipality in which the vendor was located for data analysis by geo-political boundaries. Roll-ups of municipalities were used to determine regional sales information for both AENV and Alberta Agriculture, Food and Rural Development regional boundaries. In most situations, agricultural sales made at a vendor located in a city were consolidated to the surrounding rural municipality (e.g., Camrose).

2.5.5.4 Irrigation Districts

There are 13 irrigation districts in Alberta, which are supplied primarily from rivers originating in the Rocky Mountains (Belly, St. Mary's, Oldman and Bow Rivers). They vary in size from the smallest (Ross Creek) at 490 ha to the largest (Eastern ID) at 113 548 ha. Irrigation districts comprise both irrigated and non-irrigated land, and it is not possible with this dataset to differentiate between pesticides use on dryland or irrigated land. Also, vendor locations may or may not fall within the boundaries of an irrigation district, therefore sales in the irrigation districts of Alberta is not an accurate picture of pesticide use in the districts. More detailed surveys of actual pesticide use under dryland and irrigation conditions are required to verify these estimates. For this study, it was possible to identify specific products that would be used on specialty crops (sugar beets, potatoes, corn) in this region, as well as broader spectrum products that are sold within the irrigation districts. The irrigation districts are:

- Mountain View
- Leavitt
- Aetna
- United
- Magrath
- Raymond
- Lethbridge Northern
- Taber
- St. Mary River
- Ross Creek
- Bow River
- Western
- Eastern

3.0 Results

In 1998, a total of 9 300 497 kg of active ingredient was sold in Alberta. The sales data are broken down as follows.

3.1 Type of Use

Herbicides and plant growth regulators (PGR's) made up the majority of pesticides sold in Alberta, at 76.7% (Table 1). Although insecticides made up a greater proportion than fungicide sales in 1998, this was primarily attributed to an extensive Lygus bug outbreak, which resulted in over 1.4 M acres being sprayed throughout Alberta. As insecticide use was unusually high in 1998, it is expected that fungicide sales would exceed insecticide sales in non-outbreak years.

Table 1. Pesticide Sales by Type of Use

Type of Use	Kg ai	Percentage (%)
Herbicides, PGR's	7 130 643.1	76.67
Insecticides, Acaracides, Repellents	501 044.2	5.39
Fungicides	338 628.1	3.64
Vertebrate Control Products and Vertebrate Repellents	1 594.5	0.02
Adjuvants and Surfactants	1 325 320.1	14.25
Other	3 267.8	0.04
Totals	**9 300 497.8**	**100**

Vertebrate control products and repellents made up a very small percentage of pesticide sales, at less than 0.02%. The majority of this was for products used for controlling Richardson's ground squirrel and pocket gophers.

Adjuvants and surfactants made up the second largest group, in terms of percentage of sales. These compounds are often packaged with herbicides, and are used to enhance the effectiveness of the herbicides on the target weed(s). Although they have been categorized as a separate type of use, because they are virtually always used in conjunction with a herbicide, they could be considered a component of the Herbicide group.

The "Other" category includes sales for products that do not fit the named categories, and for which only a limited number of sales records were received. This category includes wood preservatives, disinfectants, slimicides and soil fumigants. As the disinfectants and slimicides are exempted under the provincial pesticide regulations, and the focus of the sales survey was primarily on the traditional pesticides, very little information on these products was obtained.

3.2 Chemical Group

The sales records were also broken down by chemical group, as defined by the National Pesticide Sales Database groupings (Appendix 1). The chemical group with the largest proportion of sales was the Phosphonic Acids, Phosphinic Acids group at 29.9 %, followed by the Phenoxy Acids at 18.7%. The next groups were the Thiocarbamates, Oils, Mineral and Vegetable, and Nitro Derivatives in the 7-8% range. These five groups consist of the major herbicides (and adjuvants/surfactants) used in Alberta. The remaining chemical groups were all under 5%, and 27 of the 42 chemical groups were under 1% of total sales.

3.3 Sector of Use

Pesticide sales broken down by sector of use are listed in Table 3. As expected, agricultural use dominates pesticide sales in Alberta at 95.8%. The next sector was the Commercial/Industrial sector at 3.3%. Domestic pesticide sales made up only 0.77% of total sales by active ingredient. Livestock and Structural sectors combined made up only 0.1% of all sales.

Table 2. Summary of Pesticide Sales by Chemical Group (all sectors)

Chemical Group	Kg ai	Percentage (%)
Phosphonic Acids, Phosphinic Acids	2 783 525.9	29.93
Phenoxy Acids	1 742 269.9	18.73
Oils, Mineral and Vegetable	771 285.9	8.29
Thiocarbamates	734 218.3	7.89
Nitro Derivatives	682 993.8	7.34
Carboxylic Acids	431 121.9	4.64
Hydrocarbons	371 556.8	4
Benzonitriles, Nitriles	306 055.5	3.29
Organophosphorous	279 196.2	3
Cyclohexanedione Oximes	187 367.4	2.01
Dicarboximides, Oxathiin	157 861.9	1.7
Inorganics, Other	146 084.0	1.57
Aryloxyphenoxyl Acids	136 306.8	1.47
Alcohols	103 559.3	1.11
Dithiocarbamates	98 202.2	1.06
Organochlorines	68 520.9	0.74
Miscellaneous, Non-classified	40 790.6	0.44
Bacillus thuringiensis species	39 353.3	0.42
Ammoniums, Quaternary	36 352.1	0.39
Sulfonylureas, Uracils	30 834.9	0.33
Pyridines	23 733.0	0.26
Triazines, Triazinones, Tetrazines	23 364.0	0.25
Azoles, Diazoles, Oxazoles, Thiazoles, Triazoles	20 527.6	0.22
Benzimadazoles, Phenylpyrroles	18 663.0	0.2
Urea Derivatives	18 696.8	0.2

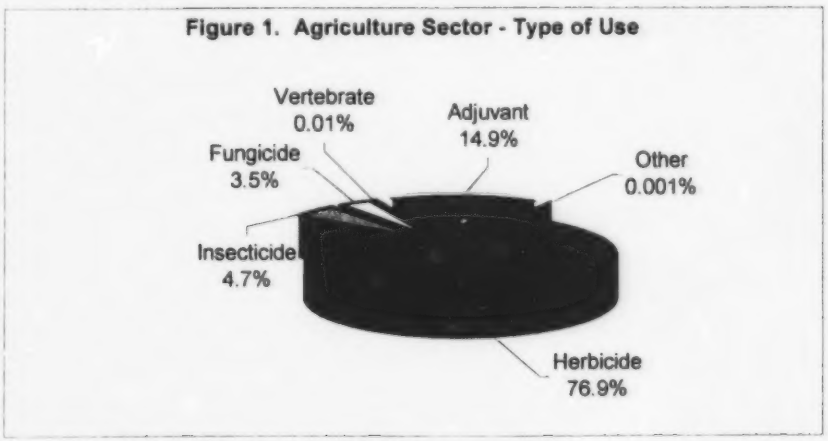
Chemical Group	Kg ai	Percentage (%)
Amides, Anilines	14 482.5	0.16
Carbamates	12 334.8	0.13
Fatty Acids	7 940.3	0.09
Diazines, Quinoxalines, Morpholines	3 875.9	0.04
Pyrethroids, Pyrethrins	2 935.8	0.03
Halogenated Hydrocarbons	1 850.9	0.02
Inorganic Coppers	1 230.4	0.01
Amino Acids	1 125.3	0.01
Phthalic Acids	1 035.0	0.01
Phenols	805.7	0.01
Chromenones	183.1	0.0
Organic Acids	148.0	0.0
Inorganic Zincs	89.2	0.0
Organometallics	16.3	0.0
Indanediones	2.1	0.0
Chlorophenols	0	0.0
Microbials – Other than Bt	0	0.0
Totals	**9 300 497.3**	**100**

Further breakdown of the sector sales by type of use was conducted to assess if the overall trends in type of use was consistent within each sector. Figures 1-3 show the breakdowns for each sector.

Table 3. Pesticide Sales by Sector

Sector	Kg ai	Percentage (%)
Agriculture	8 913 981.7	95.84
Domestic	72 024.4	0.77
Commercial/Industrial	304 881.6	3.28
Livestock	6 373.2	0.07
Structural	3 236.8	0.03
Totals	**9 300 497.7**	**100**

Figure 1. Agriculture Sector – Type of Use



Herbicides made up the majority of pesticide use in the agricultural sector, with almost 77% of all sales. Adjuvants was the next highest category, at almost 15% of pesticide use. As discussed earlier, adjuvants and surfactants are widely used to enhance the application and effectiveness of herbicides used, and are often supplied by the manufacturer to be used in conjunction with their products. Insecticide and fungicide use were both below 5% of agricultural pesticide sales in Alberta.

In order to better compare the sector sales to Quebec sector sales, the chemical group breakdown was conducted on the agricultural pesticide sales (Table 4). The Phosphonic/Phosphinic Acids group dominated the agricultural sales at over 30%, followed by the Phenoxy Acids group at just over 18%. The Oils, Thiocarbamates and Nitro Derivatives were next at 7-8% of agricultural sales.

Table 4. Summary of Agricultural Pesticide Sales by Chemical Group

Chemical Group	Kg ai	%
Phosphonic Acids, Phosphinic Acids	2 726 841.7	30.59
Phenoxy Acids	1 628 866.2	18.27
Oils, Mineral and Vegetable	767 002.9	8.60
Thiocarbamates	734 218.3	8.24
Nitro Derivatives	682 990.7	7.66
Hydrocarbons	368 704.3	4.14
Carboxylic Acids	365 508.6	4.10
Benzonitriles, Nitriles	298 994.6	3.35
Organophosphorous	263 784.0	2.96
Cyclohexanedione Oximes	187 367.4	2.10
Dicarboximides, Oxathiin	152 440.3	1.71
Aryloxyphenoxyl Acids	136 306.8	1.53
Inorganics, Other	135 613.5	1.52
Alcohols	103 151.9	1.16
Dithiocarbamates	94 743.2	1.06
Organochlorines	57 159.3	0.64
Ammoniums, Quaternary	36 043.9	0.40
Sulfonylureas, Uracils	28 776.8	0.32
Pyridines	23 695.6	0.27
Miscellaneous, Non-classified	22 112.0	0.25
Azoles, Diazoles, Oxazoles, Thiazoles, Triazoles	20 110.0	0.23
Triazines, Triazinones, Tetrazines	19 098.3	0.21
Benzimadazoles, Phenylpyrroles	18 169.0	0.20
Amides, Anilines	10 111.2	0.11
Carbamates	10 076.4	0.11
Urea Derivatives	9 015.0	0.10
Fatty Acids	4 684.6	0.05
Diazines, Quinoxalines, Morpholines	3 774.9	0.04
Pyrethroids, Pyrethrins	2 497.6	0.03

Chemical Group	Kg ai	%
Amino Acids	1 091.5	0.01
Phthalic Acids	696.3	0.01
Inorganic Coppers	277.7	0.00
Inorganic Zincs	44.5	0.00
Chromenones	7.4	0.00
Organometallics	3.8	0.00
Indanediones	1.5	0.00
Organic Acids	0.014	0.00
Phenols	0	0.00
Microbials – Other than Bt	0	0.00
Halogenated Hydrocarbons	0	0.00
Chlorophenols	0	0.00
Bacillus thuringiensis species	0	0.00
Totals	**8 913 981.7**	**100**

In the domestic sector (Figure 2), herbicides again dominated at just over 61%, however insecticide sales made up a significant proportion of pesticide sales at almost 32%. Fungicide sales were proportionately similar to agricultural fungicide sales, at around 5%.

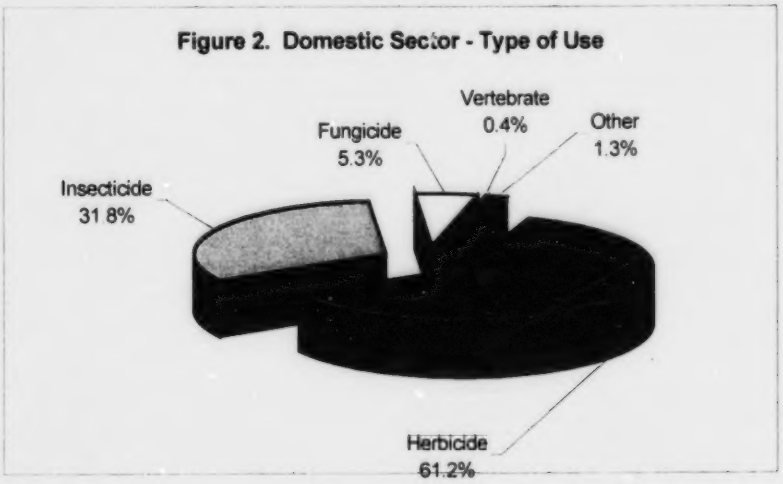


Figure 2. Domestic Sector – Type of Use

As with the agricultural products, the domestic product sales were also broken down by chemical group (Table 5) in order to compare the sales to Quebec sales figures. In the Domestic sector, the Phenoxy Acids dominated at just under 45% of total pesticide sales, followed by Inorganics and Organophosphorous, at 10%. The Phosphonic/Phosphinic Acids make up a smaller proportion of domestic sales than agricultural sales, at 9.5% compared to over 30%.

Table 5. Summary of Domestic Pesticide Sales by Chemical Group

Chemical Group	Kg ai	%
Phenoxy Acids	32 548.89	44.77
Inorganics, Other	7 504.91	10.32
Organophosphorous	7 425.49	10.21
Phosphonic Acids, Phosphinic Acids	6 929.87	9.53
Amides, Anilines	3 972.20	5.46
Oils, Mineral and Vegetable	3 005.95	4.13
Hydrocarbons	2 782.34	3.83
Carbamates	1 457.61	2.00
Fatty Acids	1 231.60	1.69
Miscellaneous, Non-classified	856.91	1.18
Phenols	805.16	1.11
Carboxylic Acids	716.07	0.98
Triazines, Triazinones, Tetrazines	647.87	0.89
Dithiocarbamates	563.70	0.78
Inorganic Coppers	450.49	0.62
Phthalic Acids	206.81	0.28
Organochlorines	194.91	0.27
Chromenones	168.12	0.23
Benzonitriles, Nitriles	147.55	0.20
Pyrethroids, Pyrethrins	128.32	0.18
Bacillus thuringiensis species	95.00	0.13
Benzimadazoles, Phenylpyrroles	69.71	0.10
Inorganic Zincs	40.00	0.06
Azoles, Diazoles, Oxazoles, Thiazoles, Triazoles	34.12	0.05
Urea Derivatives	14.68	0.02
Diazines, Quinoxalines, Morpholines	12.69	0.02
Pyridines	6.33	0.01
Ammoniums, Quaternary	3.90	0.01
Sulfonylureas, Uracils	1.49	0.00
Nitro Derivatives	1.23	0.00
Indanediones	0.28	0.00
Organometallics	0.13	0.00
Alcohols	0.02	0.00
Aryloxyphenoxyl Acids	0.018	0.00
Amino Acids	0.014	0.00
Thiocarbamates	0	0.00
Organic Acids	0	0.00
Microbials – Other than Bt	0	0.00
Imidazolinones	0	0.00
Halogenated Hydrocarbons	0	0.00
Dicarboximides, Oxathiin	0	0.00
Cyclohexanedione Oximes	0	0.00
Chlorophenols	0	0.00
Totals	**72 024.40**	**100**

In the Commercial/Industrial Sector, herbicides again dominated at 75% of pesticide sales (Figure 3). Insecticides made up just over 15%, however this was primarily associated with high volume usage of *Bacillus thuringiensis* (Bt) species for mosquito control and forest insect control operation. Fungicide sales were proportionately slightly higher in this sector, at almost 9%, reflecting fungicide sales to the golf course industry.

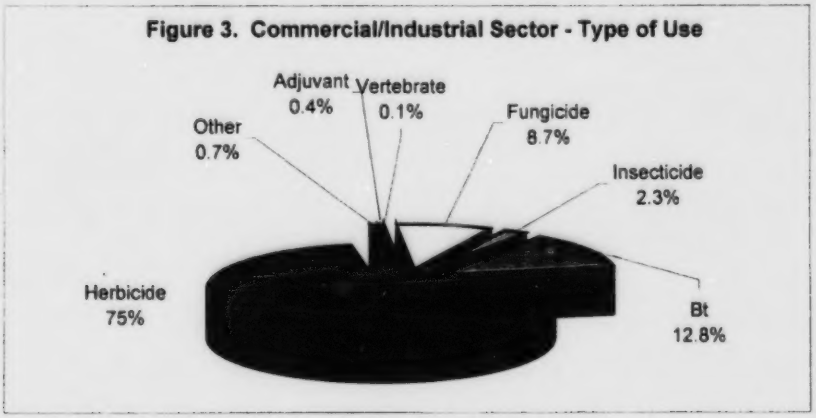


Figure 3. Commercial/Industrial Sector – Type of Use

Pesticide sales in the Livestock sector consisted of virtually all insecticides, with a small quantity of disinfectant sales also reported. The Structural sector also was dominated by insecticide sales, with a small quantity of vertebrate control products. More detailed information will be obtained when AENV conducts a use survey of the Structural sector in 2000.

3.4 Herbicide Resistance Groups

Herbicides from 19 groups were sold in Alberta in 1998, compared to the 28 groups that have been classified for Canada (Table 6).

Table 6. Agricultural Herbicide Sales by Resistance Grouping

Resistance Group	Kg ai	Percentage (%)
1. (Acetyl CoA carboxylase (ACCase) inhibitors)	323 674.2	4.72
2 (Acetolactate synthase/aceto-hydroxyacid synthase (ALS/AHAS) inhibitors)	215 185.5	3.14
3 (Microtubule assembly inhibitors)	682 965.1	9.96
4 (Synthetic auxins)	1 831 090.2	26.7
5 (Photosynthesis inhibitor at photosystem (PS) II Site A)	26 999.0	0.39

Resistance Group	Kg ai	Percentage (%)
6 (Similar to Group 5, but different binding behavior)	280 545.5	4.09
7 (Photsynthesis inhibitors at PS II Site B)	10 631.0	0.16
8 (Lipid synthesis inhibitors – not ACCase inhibition)	743 743.8	10.85
9 (EPSP* synthase inhibitors)	2 629 544.5	38.35
10 (Glutamine synthetase inhibitors)	63 400.8	0.92
11 (Bleaching: Carotenoid biosynthesis inhibitors)	1 993.2	0.03
14 (Protoporphyrinogen oxidase (PPO) inhibitors)	26.0	0.0
15 (Unknown)	4 710.0	0.07
16 (Unknown)	12 559.4	0.18
17 (Unknown)	3.8	0.0
19 (Indoleacetic acid action inhibitors)	4.8	0.0
20 (Inhibits cell wall synthesis Site A)	577.4	0.1
22 (Photo system I-electron diverters)	26 476.2	0.39
23 (Mitosis inhibitors)	679.8	0.01
25 (Unknown)	1 091.5	0.02
Non classified Herbicides	1 598.8	0.02
Totals	**6 857 500.5**	**100**

*Enolpyruvylshikimate-3-phosphate

The sales of the amino acid biosynthesis inhibitors (Groups 2, 9 and 10) made up the majority of agricultural herbicide sales in 1998, at 42.4%. These products affect amino acid synthesis, and therefore protein synthesis. Each group affects a different plant enzyme (Hall, 1996).

Sales of the auxin-like herbicides (Group 4) were next, at 26.7% of agricultural herbicide sales. This group, which is made up of phenoxy and benzoic acids, consists of some of the older and well known herbicides on the market. This group mimics the plant growth regulator indole acetic acid (auxin), and causes uncontrolled growth, resulting in unrestrained mobilization of reserves, disruption of repair mechanisms and loss of function (Hall, 1996). Auxin has several sites of action, therefore auxin herbicides act on various sites. Because of these multiple sites of action, resistance development in plants to Group 4 herbicides has been rare.

The next two groups in ranking of sales were the Group 3 (9.96%) and Group 8 (10.85%) herbicides, which are primarily pre-emergent wild oat herbicides. Resistance of wild oats and green foxtail to these products has developed in fields with a long history of repeated usage (AAFRD, 1998).

The remaining herbicide groups made up less than 5% of sales, individually, and about 10% collectively.

3.5 Geographic Distributions

3.5.1 Drainage Basin

Sales of all products were broken down by drainage basin (Table 7 and Figure 4). The Oldman River basin had the highest proportion of pesticide sales, at 20.3%. The Red Deer River basin was slightly behind at 18.8%. The North Saskatchewan River basin was next at 15.8% of pesticide sales, followed by the Battle River basin at 13.3%. The Peace River basin had just over 10% of total provincial pesticide sales, while the remaining basins were all under 10%.

Pesticide use intensity by basin (Table 7 and Figure 5) is based on total pesticide sales and total (gross) basin drainage area as reported in Martin (1996) and Environment Canada (1988). The gross basin drainage overestimates the contributing area (active drainage area) within each basin, but does provide an indication of relative size. Basin use intensity is also biased by the amount of arable and/or cultivated land within the basin.

Table 7. Pesticide Sales by River Basin – Area

River Basin	Kg ai	(%)	Area (ha) (approximate)	Use Intensity (kg/ha)
Milk River	88 309.0	0.95	401 600	0.22
South Saskatchewan River	526 369.3	5.66	1 496 600	0.35
Oldman River	1 889 054.3	20.31	2 750 800	0.69
Bow River	708 731.6	7.62	2 529 200	0.28
Red Deer River	1 748 108.3	18.8	4 678 800	0.37
Sounding Creek	126 525.9	1.36	1 007 700	0.13
Battle River	1 238 750.5	13.32	2 561 900	0.48
North Saskatchewan River	1 467 146.3	15.77	5 564 000	0.26
Beaver River	53 834.8	0.58	1 471 500	0.04
Athabasca River	331 123.9	3.56	15 862 900	0.02
Peace River	935 755.7	10.06	17 500 000	0.06
Hay River	27 154.0	0.29	5 134 400	0.005
Non-specific basin	159 634.0	1.72	N/A	N/A
Alberta	**9 300 497.6**	**100**		

The Oldman River basin had the highest relative use intensity at 0.69 kg/ha. This is the most intensively farmed area of the province, with a large proportion of cultivated land. Much of the Oldman River basin is under irrigation. The next basin in relative use is the Battle River basin, at 0.48 kg/ha. Again, the majority of this basin is under cultivation. The remaining basins have

The remaining basins have lower relative use, ranging from 0.37 kg/ha in the Red Deer basin down to 0.005 kg/ha in the Hay River basin.

The use intensity in each basin is of interest for monitoring programs, as it identifies those basins which should be focussed on for monitoring programs. Another factor that helps to relate the size and scale of drainage basins and pesticide use is river discharge. A higher annual discharge in relation to overall pesticide use intensity would indicate greater potential for dilution and less pressure on the water resources in the basin. Annual flows (over various reporting periods) were obtained from Environment Canada (1993) and are listed in Table 8. The rivers with the highest discharge have the greatest dilution capacity, and other things being equal, should have lower concentrations of pesticide residues.

The highest intensity is found in the Sounding Creek basin, one of the smallest basins in Alberta. However, personal experience in sampling Sounding Creek has identified that flow of this creek is very intermittent, and the low flow is a reflection of the low precipitation in this basin (318 mm/year at Oyen –1974-1997 annual average; 207 mm/year at Esther – 1995-1998 annual average). As well, this stream originates in the prairies, and does not have the higher elevation headwaters that provide much of the base flow for the other river basins in Alberta.

Table 8. Pesticide Sales by River Basin – Flow

River Basin (gauging station used)	Kg ai	Mean Annual Flow (dam^3)	Kg/dam^3
Milk River (Int. Border – East crossing)	88 309.0	312 000	0.283
South Saskatchewan River (Hwy 41)	526 369.3	5 180 000	0.102
Oldman River (at mouth)	1 889 054.3	2 190 000	0.863
Bow River (near mouth)	708 731.6	2 840 000	0.249
Red Deer River (at Empress)	1 748 108.3	2 220 000	0.787
Sounding Creek (at Oyen)	126 525.9	2 170	58.307
Battle River (near Sask. border)	1 238 750.5	227 000	5.457
North Saskatchewan River (Lea Park)	1 467 146.3	7 200 000	0.204
Beaver River (Cold Lake Reserve)	53 834.8	636 000	0.085
Athabasca River (below Ft. McMurray)	331 123.9	20 600 000	0.016
Peace River (Peace Point)	935 755.7	66 000 000	0.014
Hay River (near Meander River)	27 154.0	2 370 000	0.115
Non-specific basin	159 634.0	N/A	N/A
Alberta	**9 300 497.6**		

Dam^3 = cubic decametre = 1 000 m^3

The next highest basin in relation to pesticide usage and average annual flow is the Battle River basin, at 5.5 kg/dam^3. This basin is on the north boundary of the Sounding Creek basin, and also flows through the southern and eastern portion of the Aspen Parkland and Moist Mixedgrass regions of the province, regions that experience lower levels of precipitation. As well, this is another basin that does not originate in the foothills, depending upon local snowfall and summer precipitation for primary inputs to the basin.

The other basins are all below 1 kg/dam^3, which are reflective of their higher annual flows. Most of the basins (the exception being the Beaver River) originate in the foothills or the Rocky Mountains, in whole or in part. The mainstems or tributaries that originate at higher elevations tend to supply a major proportion of the base flow for these basins.

3.5.2 Pesticide Sales by Ecoregion

Pesticide sales were also broken down by ecoregion (Figure 6) to assess pesticide sales/usage in relation to ecological regions in Alberta, which represent areas of comparable soils, climate and vegetation (Table 9). This information is of interest in relation to cropping practices that are often comparable to ecological regions, and also provide a general indicator of risk of contamination.

Pesticide sales were concentrated in five ecoregions in Alberta. The largest ecoregion (Aspen Parkland) had the greatest amount of pesticides sold, at 33% of total provincial sales. The Moist Mixed Grassland ecoregion was next at 22.6 %, followed by Peace Lowland/Boreal Transition at 17%, the Mixed Grassland at 15.4% and the Fescue Grassland/Cypress Hills ecoregion at 9.8%.

When use intensity is calculated, the Moist Mixed Grassland ecoregion has the highest use intensity at 0.67 kg ai/ha, followed by the Aspen Parkland and Fescue Grassland/Cypress Hills ecoregions at 0.5 kg ai/ha. Although the Peace Lowland/Boreal Transition ecoregion had 17% of total sales, overall use intensity was relatively low at 0.15 kg ai/ha.

Table 9. Pesticide Sales by Ecoregion

Ecoregion	Kg ai	(%)	Area (ha)	Use Intensity (kg/ha)
Aspen Parkland	3 073 153.0	33.04	5 901 232	0.52
Moist Mixed Grassland	2 101 336.7	22.59	3 157 121	0.67
Peace Lowland/Boreal Transition	1 585 861.3	17.05	10 376 038	0.15
Mixed Grassland	1 432 542.1	15.4	4 660 407	0.31
Fescue Grasslands, Cypress Hills	913 942.6	9.83	1 815 757	0.50
Non specific ecoregion	159 634.0	1.72	N/A	N/A
Mixed Boreal Upland	31 459.1	0.34	22 568 703	0.001
Western Alberta Uplands	2 100.8	0.02	9 042 489	0.0002
Subalpine and Alpine	468.2	0.01	4 741 074	0
Northern Alberta Uplands	0	0.0	2 396 502	0
Athabasca Plains	0	0.0	1 254 078	0
Alberta	**9 300 497.8**	**100**		

3.5.3 Pesticide Sales by Municipality, AENV and AAFRD Regions

Pesticide sales were broken out by rural municipality to provide a detailed geo-administrative overview of sales, using municipal boundaries that are familiar to many individuals and various levels of government. The largest volume of sales (>500,000 kg ai) occurred in the County of Lethbridge and the MD of Taber, which are major supply and distribution centres for southern Alberta, particularly the irrigated region of Alberta. Municipalities with greater than 300 000 kg ai of sales were the Counties of Vulcan, Vermilion River, Red Deer and Wheatland. These are large municipalities containing the highest proportion of total crop area in Alberta (AAFRD 1999c), with intensive agricultural production. Data on primary crops grown in 1996 in the six municipalities with highest sales was derived from AAFRD (1999c)(Table 10). Acreages for major crop groups varied between municipality, however cereals (primarily wheat) dominated in each municipality. Oilseeds (primarily canola) had relatively high acreage in Vermilion River and Wheatland, but relatively low acreage in Taber and Lethbridge. Potatoes and sugar beets accounted for most of the Other Field Crops grown in Taber and Lethbridge, while field peas were extensively grown in Vermilion River. Vegetable production was predominately in the irrigated municipalities of Taber and Lethbridge. The range of crop types in various municipalities influences the type of pesticides used, as well as the use intensity (rate and frequency of application). Potatoes and sugar beets use very different products than cereals and oilseeds, and pesticide use is often more intensive on these types of crops for disease suppression, weed control and insect control. This is reflected in the use intensities for Taber and Lethbridge,

which are relatively high at over 2.5 kg/ha. These municipalities may also serve as regional supply centres, so the use intensities for these two may be a slight overestimation.

Table 10. Crop Groups Grown in High Pesticide Sales Municipalities (hectares), With Agricultural Sales (kg ai) and Use Intensity (kg ai/ha)

Crop Group	Taber	Lethbridge	Wheatland	Red Deer	Vulcan	Vermilion River
Cereals (Wheat, oats, barley, etc	134 925	171 178	217 077	152 870	212 613	214 977
Oilseeds (Canola, flaxseed, mustard)	14 929	24 609	44 596	19 082	35 789	55 043
Other Field Crops (Potatoes, Peas, Sugar Beets, etc)	22 937	9 210	2 167	3 529	2 182	6 879
Vegetables (Sweet corn, etc)	3 337	367	17	39	1	18
Hay and Forage	18 729	19 626	19 228	63 836	10 587	23 015
Total Hectares	194 857	224 990	283 085	239 356	261 172	299 932
Kg ai	519 053.3	562 955.4	385 152.6	306 547.0	315 699.7	358 663.4
Kg/ha	**2.66**	**2.50**	**1.36**	**1.28**	**1.21**	**1.20**

Sales for all of the municipalities are summarized in Table 11. Some municipalities that have very low sales may not be indicative of pesticide use in that municipality, as there are few, if any, vendors in those municipalities. However there is some agricultural production in those municipalities (i.e., Acadia, Brazeau, Ranchland, Saddle Hills), and pesticide products would have been brought in from surrounding municipalities that had vendors. Pesticides sold in the National Parks were primarily lawn and garden products. A graphical depiction of pesticide sales with municipal boundaries is given in Figure 7.

Table 11. Pesticide Sales by Municipality

Municipality	Kg ai	Municipality	Kg ai	Municipality	Kg ai
Lethbridge	570878.8	Westlock	143180.8	Peace	58279.8
Taber	522806.6	Minburn	141406.7	Northern Lights	51926.2
Wheatland	387109.3	Wainwright	141197.6	Special Area 4	45332.1
Vermilion River	359674.3	Lamont	131521.7	Athabasca	44166.0
Vulcan	315876.0	Mackenzie	124406.7	Big Lakes	43168.1
Red Deer	314630.4	Lacombe	118789.9	Bonnyville	41444.3
Flagstaff	290548.4	Strathcona	114132.2	Clear Hills	37845.0
Camrose	260686.0	Two Hills	111359.3	Special Area 2	36551.3
Rocky View	256804.4	Leduc	109722.0	Edmonton	34814.4

Municipality	Kg ai	Municipality	Kg ai	Municipality	Kg ai
Kneehill	256784.1	Starland	108328.4	Woodlands	29970.6
Forty Mile	255335.6	Spirit River	104149.2	Thorhild	23649.6
Willow Creek	246542.7	Stettler	103858.6	Lesser Slave River	4981.2
Cypress	218076.2	Fairview	101475.1	Clearwater	4179.7
Drumheller	192238.1	Provost	96377.5	Greenview	2336.9
Mountain View	188243.0	Wetaskiwin	94913.1	Yellowhead	1836.6
Grande Prairie	186631.1	St. Paul	85724.8	Wood Buffalo	951.9
Foothills	173380.4	Calgary	84674.6	Lakeland	742.9
Special Area 3	173253.4	Parkland	81230.0	Ranchland	260.7
Warner	170810.8	Ponoka	80699.9	Lac Ste. Anne	234.6
Beaver	170563.0	Smoky Lake	80099.7	Brazeau	156.6
Newell	169097.3	Paintearth	76647.8	Bighorn	96.0
Cardston	167378.6	Birch Hills	73976.6	National parks	55.4
Sturgeon	167109.9	Barrhead	69543.8	Saddle Hills	32.6
Alberta (non specific)	159634.0	Pincher Creek	64125.7	Opportunity	0.2
Smoky River	159489.5	East Peace	62361.0	Acadia	0
				Total	**9 300 497.3**

Pesticide sales were also broken down by Alberta Environment (AENV) regions (Figure 8), primarily to identify relative usage for program planning and resource deployment for pesticide regulatory programs (Table 12). The regions with the highest quantity of sales were Parkland and Prairie regions, at over 2.5 M kg ai, followed by the Bow Region at just under 1.9 M kg ai. The region with the smallest sales volume was the North East Slopes region at just over 326 000 kg ai.

Table 12. Pesticide Sales by AENV Region

AENV Region	Sales (kg ai)
Parkland	2 795 198.2
Prairie	2 532 091.8
Bow	1 883 670.4
Northwest Boreal	1 010 950.4
Northeast Boreal	592 825.1
Northeast Slopes	326 137.6
Alberta (non-specific)	159 634.0
Total	**9 300 507.5**

Agricultural pesticide sales were also broken out by Alberta Agriculture, Food and Rural Development regions (Figure 8), for use in program planning (Table 13). Highest sales were in the Southern region at over 3.2 M kg ai, followed by the Northern region at 2.7 M kg ai. The Peace region was the lowest in agricultural pesticide sales, at just under 1 M kg ai.

Table 13. Agricultural Pesticide Sales by AAFRD Region

AAFRD Region	Sales (kg ai)
Southern	3 225 351.0
Northern	2 734 174.2
Central	1 977 926.2
Peace	967 122.0
Alberta (non-specific)	9 417.8
Total	**8 913 991.2**

3.5.4 Pesticide Sales by Irrigation District

Pesticide sales were broken down by irrigation district to give an indication of the intensity of pesticide use in the irrigated areas of Alberta. As discussed earlier, the irrigation districts may or may not have vendors located within their boundaries (Figure 9), therefore the sales and usage linkage assumption in this case is not strong. Information on total acreage of crops grown in the irrigation districts, and acreage under irrigation in 1998 was obtained from AAFRD (1999b), and are also listed in Table 14.

Table 14. Pesticide Sales by Irrigation District

Irrigation District	Kg ai	Acres Irrigated	Total Assessed Acres
Mountain View	0	1 053	3 722
Leavitt	42 712.6	4 600	4 769
Aetna	0	1 930	3 519
United	0.2	17 276	34 353
Magrath	124 665.8	11 189	18 300
Raymond	25 080.1	32 259	45 533
Lethbridge Northern	453 922.6	122 379	153 365
Taber	255 669.8	76 872	80 455
St. Mary River	411 681.6	342 758	360 780
Ross Creek	39 253.3	1 055	1 210
Bow River	201 109.0	198 197	210 690
Western	298 181.1	67 643	86 771
Eastern	169 097.3	274 942	280 573
Totals	**2 021 373.4**	**1 152 153**	**1 284 040**

The table shows that there is not a very good correlation between kg ai sold and the area farmed (assessed) or irrigated. For example, only 0.2 kg of pesticide sales could be attributed directly to the United irrigation district, yet over 34 000 acres were farmed. On the other hand, almost 300 000 kg ai of pesticide sales were attributed to vendors within the Western irrigation district, yet just over 86 000 acres were farmed. Because of the relatively small sizes of the irrigation districts

in relation to the size of trading areas associated with some vendors, the direct association between sales and acreage farmed (with or without irrigation) in the irrigation districts is not possible. Detailed pesticide use data would be required to delineate pesticide use under irrigation.

Figure 4. Total Pesticide Sales By River Basin ('000 kg ai) - 1998

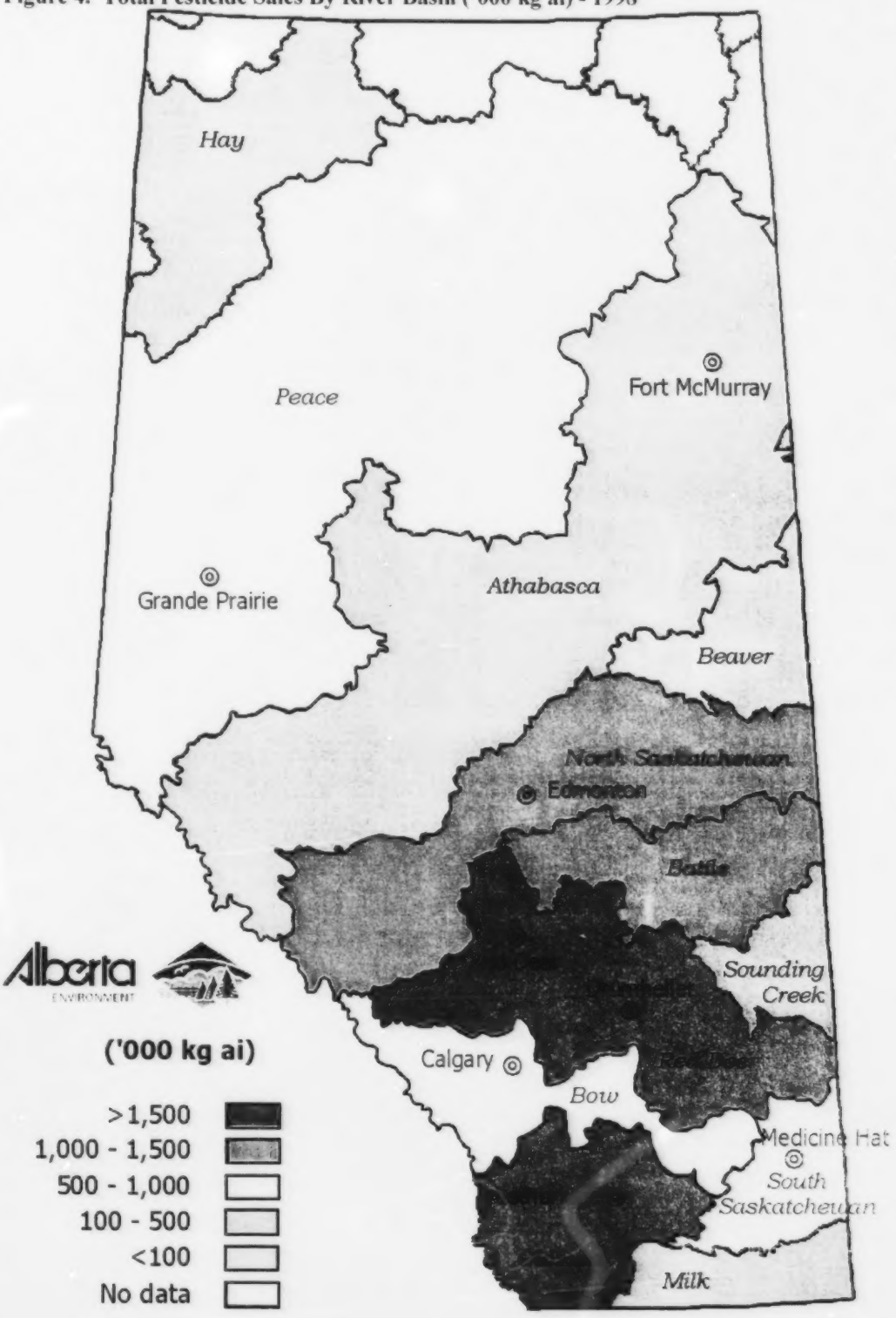


Figure 5. Estimated Pesticide Use Intensity by River Basin (kg ai/ha) - 1998

Figure 6. Total Pesticide Sales by EcoRegion ('000 kg ai) - 1998

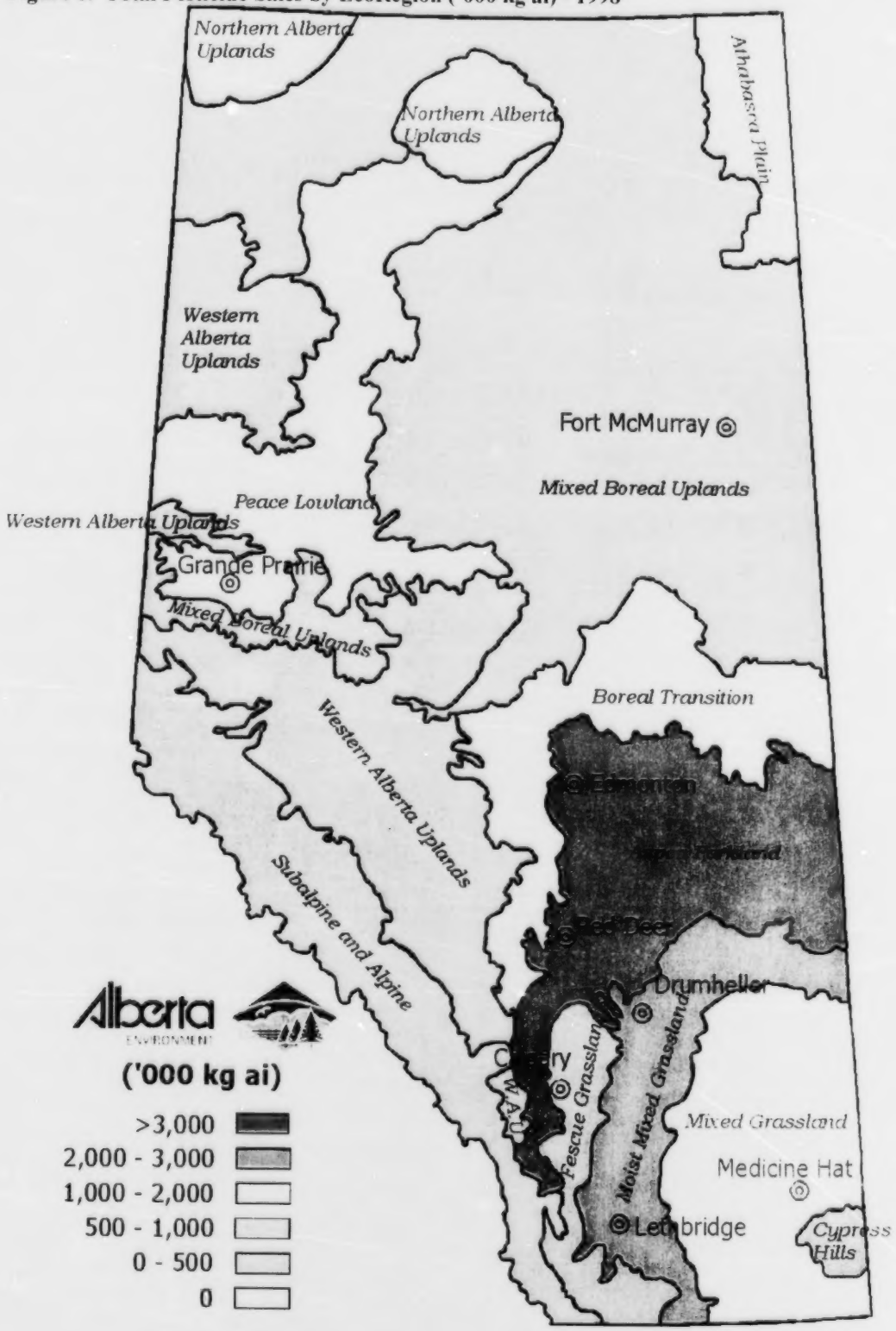


Figure 7. Total Pesticide Sales by Municipality ('000 kg ai) - 1998

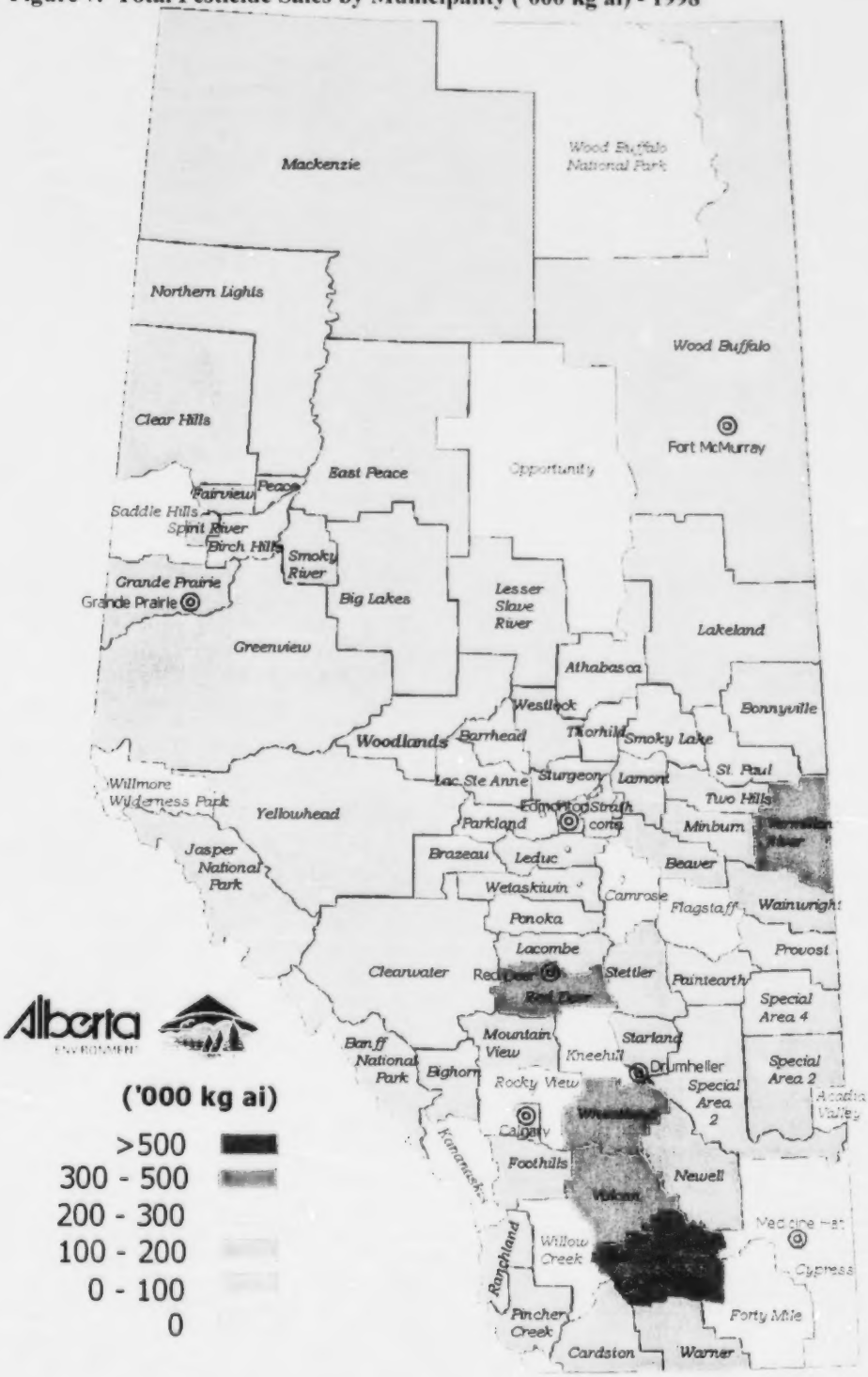


Figure 8. Alberta Government Regions

Figure 9. Irrigation Districts in Alberta

4.0 Discussion

4.1. Use Intensity

One of the measurements used to compare relative pesticide use between different geographic areas is use intensity, usually measured as kg ai/ha. Using 1993 agricultural pesticide sales data, and adjusting the data to compensate for the proportion of sales data obtained in that year, it was estimated that pesticide use intensity in Alberta was 0.8 kg ai/ha (AENV 1998). Using a more comprehensive data set from 1998, total agricultural pesticide sales of 8 913 982 kg was divided by the 1996 total cropland in Alberta (9 546 886 ha – AAFRD 1999c) to arrive at a pesticide use intensity of 0.93 kg ai/ha. However, data on sales of adjuvant was not collected in 1993, and a more accurate comparison was obtained by removing that component from the agricultural sales of 1998 (1 325 320 kg), which resulted in a revised use intensity of 0.79 kg ai/ha. The 1993 use intensity value was an estimation (a conscious over-estimate to compensate for the limited data available), and the similarity between pesticide use intensity in 1993 and 1998 on its own does not indicate that pesticide use remained unchanged from 1993 to 1998. In fact, other information on national pesticide sales from 1994 to 1998 ($1.0 to $1.4 billion – CPI 2000) and recovery of pesticide containers collected in Alberta (736 225 in 1993 to 1.2 M containers in 1998 – Curtis Construction - annual summaries) suggests that pesticide use has increased over the five years. However this apparent trend could be due to replacement of lower cost pesticides with higher cost pesticides, and replacement of products sold in bulk or refillable containers with products sold in non-refillable containers. Subsequent pesticide sales surveys may improve the ability to detect trends in pesticide use intensity in Alberta.

Within Alberta, highest agricultural use intensities were reported for the rural municipalities of Taber and Lethbridge. This is related to the intensive agricultural production undertaken in these municipalities and relatively large acreages of specialty crops under irrigation. Part of the reason for the high use intensities could be related to the fact that these municipalities (esp. Lethbridge) may have vendors that serve a larger area than the immediate municipality.

However, when compared to other regions, Alberta's overall pesticide use intensity at 0.79 kg/ha is at the lower end of the spectrum. Although total pesticide sales in Quebec are substantially lower than in Alberta, pesticide use intensity was much higher (3.2 kg/ha in 1997 – Gorse 1999). This was predominately due to high application rates (3 kg/ha) on their large acreage crops (corn and soybean), and even higher rates on specialty crops like potatoes, tobacco and apples. Overall,

pesticide use in Quebec has declined over recent years, and agricultural pesticide use intensity has declined from 3.8 kg/ha in 1993 to 3.2 kg/ha in 1997 (Gorse 1999).

Other regions report even higher use intensity rates. The agricultural use intensity in the US in 1997 was estimated to be 2.8 kg/ha (EPA 1999), European use intensity ranges from 4-6 kg/ha, Japan is at 7.7 kg/ha (AENV 1998), and California agricultural use intensity was calculated to be 24.9 kg/ha (USDA 2000, CDPR 1999).

4.2 Pesticide Sales Data for Quebec

Because Quebec is the only other province to publish recent detailed sales information, comparison with Alberta sales data can be undertaken. Quebec's agricultural pesticide use showed a different range of products sold, which relates to the primary crops planted in Quebec (corn and soybean), compared to wheat, barley and canola here in Alberta. Agricultural sales in Quebec were substantially lower at 2 732 751 kg ai (Gorse, 1999), compared to almost 9 M kg ai in Alberta. The Amides group dominated agricultural sales in Quebec at 18.5%, compared to Alberta Amides, Aniline sales at 0.11%. The Triazines were the next largest group in Quebec at 15.8%, compared to Alberta at 0.21%. Products from these groups are primarily used on corn and soybean, of which very little acreage occurs in Alberta. Following the Triazines were the Dithiocarbamates at 10.5%, then the Oils, Mineral and Vegetable at 10.4%. On the other hand, Alberta has high acreages of cereals and canola, for which Phosphonic/Phosphinic Acids and Phenoxy Acids are primarily used on. The pre-emergent herbicides (Thiocarbamates and Nitro Derivatives) are also extensively used in cereal production, more than for corn or soybeans.

Their smaller acreage in crops (848 201 ha) compared to Alberta's cropped acreage of 9 546 886 ha is also reflected in their much lower agricultural sales (2 732 751 kg vs 8 913 982 kg), even with a higher use intensity.

A comparison of domestic sales data highlights some important differences. In Alberta, phenoxy herbicides were the biggest component of domestic sales, with over half (61.6%) of the phenoxy acids (2,4-D and mecoprop mainly) originating from weed and feed formulations sold in granular or liquid form. Quebec does not collect sales data on weed and feed formulations, while the remaining phenoxy herbicide sales data made up a small quantity of domestic sales (15 908 kg ai – 5.5%)(Gorse 1999). On the other hand, their Ornamental Horticulture sector, which includes lawncare companies, municipal governments, golf courses and other related facilities, had

phenoxy herbicide sales of over 72 000 kg, 71% of pesticide sales to this sector. It would appear from the sales data that in Quebec, a large proportion of lawn weed control is conducted by commercial lawn care companies. On the other hand, the lack of sales data on weed and feed formulations may actually underestimate the homeowners use of phenoxy herbicides. In both provinces, phenoxy herbicides are likely the most used herbicides in the domestic sector, even though this may not be apparent in a cursory comparison of sales data.

Sales of domestic insecticides were also markedly different in Quebec and Alberta. Domestic pesticide sales were higher in Quebec (289 127 kg ai) (Gorse, 1999) than in Alberta. The majority of products sold in Quebec were Hydrocarbons, at 49.9%, compared to Alberta at just 3.8%. The next largest group sold in Quebec was the Organochlorines, at 24.3%, compared to Alberta at 0.27%. Mothball products from these two groups made up 82% of domestic insecticide sales (Gorse 1999). Incomplete sales data was obtained from domestic product suppliers in Alberta on mothballs.

In Alberta, the Organophosphates were the largest insecticide group at 7425 kg ai, compared to 3166 kg ai for the comparable chemical group in Quebec. Given that Quebec has a much larger urban population than Alberta, this suggests that commercial operations provide the bulk of insect control in Quebec, or that Alberta has greater lawn and garden insect problems than Quebec, or that Quebec residents have a greater tolerance to lawn and garden insects.

The comparison of sales data between Quebec and Alberta illustrates the difficulty in making objective, accurate comparisons because of different crops (resulting in different products being used), different climatic conditions, and different ways of assembling and reporting information. These difficulties would apply to comparisons among Canadian provinces, as well as between Alberta and other countries.

4.3 Herbicide Tolerant Canola

The advent of herbicide tolerant canola (HTC) (Roundup Ready canola, Liberty Link canola, Pursuit Smart canola, etc) during the 1990's has changed crop production practices and pesticide use substantially. Estimated acreage of herbicide tolerant canola seeded in Alberta in 1998 was 1 073 871 ha (Thomas 2000, Canola Council 2000). Comparing 1993 to 1998 sales for the herbicide products associated with HTC (Roundup, Liberty and Pursuit) is difficult, as the Prairie versions of Liberty and Pursuit were only registered in 1995. Roundup, however, has been

registered for a number of years, and comparing the Phosphonic/Phosphinic Acid sales for 1993 (adjusted) and 1998 (actual) shows a 162% increase in sales for this group over the five years. Part of this increase can be attributed to label expansions for these products (pre-harvest application with Roundup being the primary expansion), but a portion of the increase can be attributed to the HTC acreage. Overall canola acreage in Alberta increased 21% between 1993 and 1998 (Canola Council 2000).

4.4 Herbicide Resistance

Resistance to herbicides is a function of repeated use of herbicides from the same group and resistance susceptible weeds. In Western Canada, large numbers of sites with confirmed weed resistance have been reported for Groups 1, 2, 3 and 8 (Hall et al. 1999).

The Group 1, 3 and 8 compounds have been used in Alberta for many years, primarily for wild oat control. Repeated use of some of these compounds (especially triallate – Group 8) has led to an extensive number of sites with established wild oat resistance. The Group 9 products, at almost 11% of agricultural herbicide sales, are still relatively widely used in Alberta. The Group 3 compounds (ethalfluralin and trifluralin primarily) are still widely used, at almost 10% of herbicide sales and have a large number of reported sites with green foxtail resistance in Alberta (Hall et al. 1999). The Group 1 herbicides ('fops and 'dims) also have a large number of sites in Western Canada with reported weed resistance for wild oats and green foxtail. Although the use of Group 1 herbicides is about half that of Group 3's or Group 8's, resistance as an issue with Group 1's is nearly as important as in the other groups.

However, the level of use alone is not a major factor in assessing the potential for herbicide resistance. For example, no resistance has been reported for Group 9 and 10 herbicides in Western Canada (Hall et al. 1999). Resistance to Group 9 herbicides has been reported from Australia (Heap, 1997) and given the extensive use (over 38% of herbicides) of Group 9 herbicides in Alberta (wide acreage sprayed and multiple annual applications in some cases), the potential for development of Group 9 resistance in Alberta is a concern to the agricultural industry. The Group 2 herbicides (sulfonylurea's and imidazolinones) have extensive resistance development in Alberta, particularly for chickweed, with greater than 200 sites in Western Canada with reported weed resistance (Hall et al. 1999). The sulfonylurea's are applied at extremely low rates (3-15 g ai/acre, Cotton and Byrtus 1995), which, by sales volume alone, underrepresents the potential for these products to develop weed resistance. The Group 4

herbicides, at almost 27% of agricultural herbicide sales, have only one site in Western Canada with reported weed resistance (Hall et al. 1999).

The use of pesticide sales data in relation to herbicide resistance is best utilized when trends can be discerned. In 1988-1993, trends in several pesticides were observed to be decreasing in sales (triallate, trifluralin and difenzoquat), while ethalfluralin was increasing. Comparing the Group 3 herbicides sold in 1993 (751 834 kg ai) to the Group 3 herbicides sold in 1998 (682 965 kg ai), shows a decrease, especially as the sales data from 1998 is much more comprehensive. Sales of Group 8 herbicides in 1993 (452 889 kg ai) compared to 1998 sales (734 744 kg ai) would appear to be increasing. Given that sales reported in 1993 were estimated to be approximately ½ of actual sales (Cotton and Byrtus 1995), a doubling of 1993 sales to 905 778 kg ai would suggest that sales of Group 8 herbicides in 1998 have also decreased, albeit not as much as the Group 3 herbicides.

4.5 Drainage

Highest overall sales of pesticides was in the Oldman River basin, however highest use relative to annual basin flow was found to be in the Sounding Creek and Battle River basins. This information has implications for defining priorities in existing and future monitoring programs. For example, there is only one stream site currently being sampled on a long-term, regular basis in the Sounding Creek basin, and only two sites in the Battle River basin. Intermittent flows of the Sounding Creek further limit the monitoring data available for this basin.

On the other hand, a basin like the Oldman River has a number of long-term monitoring sites that include pesticide analysis, and a current large scale monitoring program for the basin has added a number of additional sites that include samples for pesticide analysis. The number of sites sampled in any one basin reflects the importance of the water to agricultural, industrial and residential development, rather than the perceived risk of pesticide contamination.

5.0 Conclusions

This overview of pesticide sales data collected for 1998 provides a general framework for pesticide program review and comparisons to other regions, however more detailed analysis of the data will be required for utilization in monitoring program development in Alberta. This overview will also provide the information to better base decisions on future regulatory changes. Future surveys of pesticide sales in Alberta will assist in keeping pesticide use in perspective and measuring overall use trends.

Key results of the 1998 survey are:

- Total sales volume was just over 9.3 M kg of active ingredient.
- Herbicides and plant growth regulators made up 76.7% of the total sold.
- Of the chemical groups, the Phosphonic/Phosphinic Acid group had the highest sales, comprising 29.9% of total pesticide sales.
- The Agriculture sector accounted for 95.8% of all pesticides sold in Alberta, with 76.9% of that being herbicides, and 4.7% being insecticides. The insecticide sales volume was relatively high for Alberta, as 1998 was an outbreak year for Lygus bug.
- The Domestic sector accounted for 0.8% of total pesticide sales, with herbicides making up 61.2% and insecticides 31.8%.
- Of the herbicide resistance groups, the Group 4 and Group 9 herbicides made up the largest proportion of sales at 26.7% and 38.35%, respectively.
- Spatially, the Oldman River and Red Deer River basins had the largest quantities of sales by river basin at over 1.7 M kg ai, while the Oldman River basin had the highest use intensity at 0.69 kg ai/ha.
- The Aspen Parkland ecoregion had the largest quantity of sales by ecoregion, at just over 3 M kg ai.
- Agricultural pesticide use intensity for Alberta was estimated at 0.79 kg ai/ha.

6.0 References

AAFRD. 1998. Crop Protection with Chemicals - 1998. Alberta Agriculture, Food and Rural Development. Edmonton. Agdex 606-1. 413 pp.

AAFRD. 1999a. Ecoregions, Ecodistricts and AESA Soil Quality Monitoring Sites. Alberta Agriculture, Food and Rural Development. (http://www.agric.gov.ab.ca/images/sustain/benchmarks.jpg) (October 6, 1999)

AAFRD. 1999b. Crops Grown Within the Thirteen Irrigation Districts – 1998. Alberta Agriculture, Food and Rural Development. (http://www.agric.gov.ab.ca/irrigate/stats/main.html) (February 2, 2000)

AAFRD, 1999c. 1996 Alberta Municipality Agriculture Profile, Peace Region, Northwest Region, Northeast Region, Central Region, South Region. Alberta Agriculture, Food and Rural Development, Production Economics and Statistics Branch. Edmonton. 5 volumes.

AENV. 1998a. Pesticide Use in Alberta. Alberta Environment. Pesticide Management Program, Edmonton. 4 pp (http://www.gov.ab.ca/env/protenf/pesticide/)

AENV. 1998b. Pesticide Vendor Registrations (Blue List). June 1998. Alberta Environment, Pesticide Management Program, Edmonton. 37 pp.

AEP. 1994. Natural Regions and Subregions of Alberta: Summary. Alberta Environmental Protection. Edmonton. 18 pp.

Anderson, A-M. 1995. Overview of Pesticide Data for Alberta Surface Waters. Appendix A4 92 pp. *in* Cross, P. et al. Phase 2. Selection of Soil Landscape Units and Study Design Considerations for the Surface Water Quality Monitoring Program. Prepared for CAESA Water Quality Monitoring Committee. Edmonton.

CAESA. 1998. Agricultural Impact on Water Quality in Alberta: An Initial Assessment. Prepared for Canada-Alberta Environmentally Sustainable Agriculture Water Quality Committee. Alberta Agriculture, Food and Rural Development. Lethbridge. 95 pp.

CDPR. 1999. Summary of Pesticide Use Report Data – 1998. Indexed by Chemical. California Environmental Protection Agency, California Department of Pesticide Regulation. Sacramento. 39 pp.

CPI. 2000. 1998 Sales Survey Pest Control Product in Canada. Report and Discussion. Crop Protection Institute. Etobicoke, Ontario. 5 pp. (http://www.cropro.org/ENG/sales/sales97.htm) (April 10, 2000)

Cotton, M.M. and G. Byrtus. 1995. Pesticide Sales Trends in Alberta. Appendix A2. 66 pp *in* Cross, P. et al. Phase 2. Selection of Soil Landscape Units and Study Design Considerations for the Surface Water Quality Monitoring Program. Prepared for CAESA Water Quality Monitoring Committee. Edmonton.

Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological

Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. 121 pp report and national map at 1:7 500 000 scale.

Environment Canada. 1988. Surface Water Data Reference Index. Water Survey of Canada. Ottawa. 408 pp.

EPA. 1999. Pesticides Industry Sales and Usage. 1996 and 1997 Market Estimates. United States Environmental Protection Agency. Office of Pesticide Programs. Report 733-R-99-001. Washington, D.C. 39 pp.

Gregoire, F. 1997. Overview of 1995 Pesticide Sales in Quebec. Quebec Department of Environment and Wildlife, Pesticides Division. 19 pp.

Gorse, I. 1999. Bilan des ventes de pesticides au Quebec en 1997. Directions des politiques du secteur agricole, Division des pesticides. Ministere de L'Environnement du Quebec, Envirodoq EN950037, PES-14, 116 pp.

Hall, L. 1996. How Herbicides Work: Mechanisms of Action. Alberta Agriculture, Food and Rural Development, Agdex 606-2. Edmonton. 56 pp.

Hall, L., H. Beckie and T.M. Wolf. 1999. How Herbicides Work: Biology to Application. Alberta Agriculture, Food and Rural Development. Agdex 606-2. Edmonton. 134 pp.

Heap, I.M. 1997. The Occurrence of Herbicide-Resistant Weeds Worldwide. Pesticide Science. 51:235-243.

Martin, F.R.J. 1996. Addendum #7 to Hydrology Report #104. The Determination of Gross and Effective Drainage Areas in the Prairie Provinces. PFRA, Regina. 109 pp.

OECD, 1999. OECD Survey on the Collection and Use of Agricultural Pesticides Sales Data: Survey Results. OECD Env. Health and Safety Publications, Series on Pesticides No. 7. Paris. 40 pp.

PMRA. 1999. Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action. Regulatory Directive DIR99-06. Pest Management Regulatory Agency, Ottawa. 24 pp. (http://www.hc-sc.gc.ca/pmra-arla/dir9906-e.pdf)

Strong, W.L. and J.M. Thompson. 1995. Ecodistricts of Alberta: Summary of Biophysical Attributes. Prepared for Alberta Environmental Protection, Edmonton. 92 pp. + maps.

USDA. 2000. 1997 Census of Agriculture – State Data. US Department of Agriculture, National Agricultural Statistics Service.
(http://www.nass.usda.gov/census/census97/volume1/ca-5/ca1_14.pdf) (April 10, 2000)

Appendix 1. Chemical Groups and Active Ingredients

Chemical Group	Active Ingredient Name	Type of Use
Alcohols	1,2-ETHANEDIOL	Adjuvant
	NONYLPHENOXYPOLYETHOXYETHANOL	Adjuvant
	OCTYLPHENOXYPOLYETHOXYETHANOL	Adjuvant
	OCTYLPHENOXYPOLYETHOXYETHANOL PHOSPHATE ESTER	Adjuvant
	SILOXYLATED POLYETHER	Adjuvant
	TRIMETHYLNONYLPOLYETHOXYETHANOL	Adjuvant
	NONYLPHENOXYPOLYETHOXYETHANOL - IODINE COMPLEX	Disinfectant
	PROPYLENE GLYCOL	Disinfectant
	TRIETHYLENE GLYCOL	Disinfectant
	2-(HYDROXYMETHYL)-2-NITRO-1,3-PROPANEDIOL	Disinfectant
	ABAMECTIN	Insecticide
	BUTOXYPOLYPROPYLENE GLYCOL	Insecticide
	2-HYDROXYETHYL N-OCTYL SULFIDE PLUS RELATED ACTIVE COMPOUNDS	Insecticide
	S-(2-HYDROXYPROPYL)THIOMETHANE SULFONATE	Antimicrobial
	FATTY ALCOHOLS PRESENT AS N-DECANOL	Plant Growth Regulator
	FATTY ALCOHOLS PRESENT AS N-DECANOL AND N-OCTANOL	Plant Growth Regulator
	BRONOPOL	Preservative
	AZACOSTEROL HYDROCHLORIDE	Vertebrate
	CHOLECALCIFEROL	Vertebrate
	3-CHLORO-1,2-PROPANEDIOL	Vertebrate
	ERGOCALCIFEROL	Vertebrate
Amides, Anilines	POLYACRYLAMIDE	Adjuvant
	METALAXYL	Fungicide
	DIPHENYLAMINE	Fungicide
	MEFENOXAM	Fungicide
	FOMESAFEN	Herbicide
	PROPYZAMIDE	Herbicide
	DIMETHENAMID	Herbicide
	METOLACHLOR	Herbicide
	NAPROPAMIDE	Herbicide
	FLUMETSULAM	Herbicide
	ISOXABEN	Herbicide
	PROPANIL	Herbicide
	HYDROGEN CYANAMIDE	Herbicide
	TEBUFENOZIDE	Insecticide
	AMITRAZ	Insecticide
	NICLOSAMIDE	Insecticide
	DEET PLUS RELATED ACTIVE TOLUAMIDES	Insecticide
	2,2-DIBROMO-3-NITRILOPROPIONAMIDE	Antimicrobial
	NAPHTHALENEACETAMIDE	Plant Growth Regulator
	CHLOROACETAMIDE	Preservative
	N-METHYLOL CHLOROACETAMIDE	Preservative
	BONE OIL	Vertebrate

Chemical Group	Active Ingredient Name	Type of Use
Amino Acids	STREPTOMYCIN	Fungicide
	DODINE	Fungicide
	FLAMPROP-METHYL	Herbicide
	FLAMPROP-M-METHYL	Herbicide
	HYDRAMETHYLNON	Insecticide
	IMIDACLOPRID	Insecticide
	DODECYLGUANIDINE HYDROCHLORIDE	Antimicrobial
Ammoniums, Quaternary	N-ALKYL (25% C12, 60% C14, 15% C16) DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (40% C12, 50% C14, 10% C16) DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (50% C12, 30% C14, 17% C16, 3% C18) DIMETHYL ETHYLBENZYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (68% C12, 32% C14) DIMETHYL ETHYLBENZYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (50% C12, 30% C14, 17% C16, 3% C18) DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	DIDECYL DIMETHYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (5% C12, 60% C14, 30% C16, 5% C18) DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	METHYLDODECYLBENZYL TRIMETHYL AMMONIUM CHLORIDE 80% AND METHYLDODECYLXYLYLENE BIS(TRIMETHYL AMMONIUM CHLORIDE) 20%	Disinfectant
	N-ALKYL (98% C12, 2% C14) DIMETHYL 1-NAPHTHYLMETHYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (67% C12, 25% C14, 7% C16, 1% C18) DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	DIISOBUTYLPHENOXYETHOXYETHYL DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (5% C5-18, 61% C12, 23% C14, 11% C16) DIMETHYL BENZYL AMMONIUM CHLORIDE	Disinfectant
	DISTEARYL (15% C16, 85% C18) DIMETHYL AMMONIUM CHLORIDE	Disinfectant
	DIOCTYL DIMETHYL AMMONIUM CHLORIDE	Disinfectant
	OCTYL DECYL DIMETHYL AMMONIUM CHLORIDE	Disinfectant
	N-ALKYL (3% C12, 95% C14, 2% C16) DIMETHYL BENZYL AMMONIUM CHLORIDE (OR: MYRISTYL DIMETHYL BENZYL AMMONIUM CHLORIDE DIHYDRATE)	Disinfectant
	DIQUAT	Herbicide
	PARAQUAT	Herbicide
	DIFENZOQUAT PRESENT AS METHYL SULPHATE SALT	Herbicide
	DIALKYL (8% C8, 9% C10, 47% C12, 18% C14, 8% C16, 10% C18) DIMETHYL AMMONIUM CHLORIDE	Antimicrobial
	DIALKYL (5% C12, 60% C14, 30% C16, 5% C18) METHYL BENZYL AMMONIUM CHLORIDE	Antimicrobial
	CHLORMEQUAT	Plant Growth Regulator

Chemical Group	Active Ingredient Name	Type of Use
	1-(3-CHLOROALLYL)-3,5,7-TRIAZA-1-AZONIAADAMANTANE CHLORIDE (CIS ISOMER)	Preservative
	3-(TRIMETHOXYSILYL)-PROPYLDIMETHYLOCTADECYL AMMONIUM CHLORIDE	Preservative
	DENATONIUM BENZOATE	Vertebrate
Aryloxyphenoxyl Acids	CLODINAFOP-PROPARGYL	Herbicide
	DICLOFOP-METHYL	Herbicide
	QUIZALOFOP-ETHYL	Herbicide
	FENOXAPROP-ETHYL	Herbicide
	FENOXAPROP-P-ETHYL (ISOMER)	Herbicide
	FLUAZIFOP-P-BUTYL	Herbicide
	FLUAZIFOP-BUTYL	Herbicide
	QUIZALOFOP P-ETHYL	Herbicide
Azoles, Diazoles, Oxazoles, Thiazoles, Triazoles	ETRIDIAZOLE	Fungicide
	MYCLOBUTANIL	Fungicide
	PROPICONAZOLE	Fungicide
	TRIADIMENOL	Fungicide
	TRIADIMEFON	Fungicide
	AMITROLE	Herbicide
	CLOMAZONE	Herbicide
	OXADIAZON	Herbicide
	BENTAZON	Herbicide
	SODIUM SALT OF 2-MERCAPTOBENZOTHIAZOLE	Antimicrobial
	PACLOBUTRAZOL	Plant Growth Regulator
	1,2-BENZISOTHIAZOLIN-3-ONE	Preservative
	2-METHYL-4-ISOTHIAZOLIN-3-ONE	Preservative
	5-CHLORO-2-METHYL-4-ISOTHIAZOLIN-3-ONE	Preservative
	2-N-OCTYL-4-ISOTHIAZOLIN-3-ONE	Preservative
	2-(THIOCYANOMETHYLTHIO)BENZOTHIAZOLE	Preservative
	ZINC 2-MERCAPTOBENZOTHIAZOLE	Preservative
	STRYCHNINE PRESENT AS ALKALOID OR AS SULPHATE	Vertebrate
	AZACONAZOLE	Wood Preservative
Bacillus thuringiensis species	BACILLUS THURINGIENSIS BERLINER SSP KURSTAKI	Insecticide
	BACILLUS THURINGIENSIS SSP. SAN DIEGO	Insecticide
	BACILLUS THURINGIENSIS, SEROTYPE H-14	Insecticide
	BACILLUS THURINGIENSIS SSP. TENEBRIONIS	Insecticide
Benzimadazoles, Phenylpyrroles	BENOMYL	Fungicide
	CARBENDAZIM	Fungicide
	THIOPHANATE-METHYL	Fungicide
	THIABENDAZOLE	Fungicide
	FLUDIOXONIL	Fungicide
	CARBENDAZIM-PHOSPHATE	Fungicide
Benzonitriles, Nitriles	CHLOROTHALONIL	Fungicide

Chemical Group	Active Ingredient Name	Type of Use
	BROMOXYNIL PRESENT AS THE ESTER OF N-OCTANOIC ACID OR N-PENTANOIC ACID	Herbicide
	DICHLOBENIL	Herbicide
Carbamates	PROPAMOCARB HYDROCHLORIDE	Fungicide
	ASULAM	Herbicide
	CHLORPROPHAM	Herbicide
	ALDICARB	Insecticide
	AMINOCARB	Insecticide
	PROPOXUR	Insecticide
	BENDIOCARB	Insecticide
	CARBARYL	Insecticide
	CARBOFURAN	Insecticide
	FORMETANATE HYDROCHLORIDE	Insecticide
	METHIOCARB	Insecticide
	METHOMYL	Insecticide
	OXAMYL	Insecticide
	PIRIMICARB	Insecticide
	IODOCARB	Wood Preservative
Carboxylic Acids	BENZOIC ACID	Adjuvant
	GLYCOLIC ACID	Disinfectant
	OXINE BENZOATE	Fungicide
	ACIFLUORFEN	Herbicide
	IMAZYPYR	Herbicide
	IMAZAMETHABENZ	Herbicide
	IMAZETHAPYR	Herbicide
	IMAZAMOX	Herbicide
	DICAMBA PRESENT AS ACID, AS DIETHANOLAMINE SALT, AS DIMETHYLAMINE SALT, OR AS BUTOXYETHYL ESTER	Herbicide
	CLOPYRALID	Herbicide
	PICLORAM PRESENT AS ACID OR AS ISOOCTYL ESTERS OR AS POTASSIUM SALT	Herbicide
	PICLORAM PRESENT AS AMINE SALTS (ALKANOLAMINE SALT, DIETHANOLAMINE SALT, OR TRIISOPROPANOLAMINE SALT)	Herbicide
	TRICLOPYR	Herbicide
	CHLORAMBEN PRESENT AS AMMONIUM SALT OR AS SODIUM SALT	Herbicide
Chlorophenols	2,4,4'-TRICHLORO-2'-HYDROXYDIPHENYL ETHER [OR 5-CHLORO-2(2,4-DICHLOROPHENOXYL)PHENOL]	Disinfectant
	4-CHLORO-3,5-XYLENOL	Disinfectant
	SODIUM O-BENZYL-P-CHLOROPHENATE	Disinfectant
	DICHLOROPHEN	Insecticide
	O-BENZYL-P-CHLOROPHENOL	Antimicrobial
	PENTACHLOROPHENOL PLUS RELATED ACTIVE CHLOROPHENOLS	Wood Preservative
Chromenones	ROTENONE	Insecticide
	BRODIFACOUM	Vertebrate
	BROMADIOLONE	Vertebrate
	WARFARIN PRESENT IN FREE FORM OR AS SODIUM SALT	Vertebrate

Chemical Group	Active Ingredient Name	Type of Use
Cyclohexanedione oximes	CLETHODIM	Herbicide
	SETHOXYDIM	Herbicide
	TRALKOXYDIM	Herbicide
Diazines, Quinoxalines, Morpholines	TRIFORINE	Fungicide
	DIMETHOMORPH	Fungicide
	DODEMORPH-ACETATE	Fungicide
	CHINOMETHIONAT	Fungicide
	FENPROPIMORPH	Fungicide
	QUINCLORAC	Herbicide
	PYRAZON	Herbicide
	PYRIDATE	Herbicide
	PYRIDABEN	Insecticide
	ANCYMIDOL	Plant Growth Regulator
	6-BENZYLAMINOPURINE (OR: 6-BENZYLADENINE)	Plant Growth Regulator
	MALEIC HYDRAZIDE	Plant Growth Regulator
	SULFAQUINOXALINE PRESENT AS SODIUM SALT	Vertebrate
Dicarboximides, Oxathiin	IPRODIONE	Fungicide
	VINCLOZOLIN	Fungicide
	OXYCARBOXIN	Fungicide
	CARBATHIIN	Fungicide
Dithiocarbamates	FERBAM	Fungicide
	MANEB	Fungicide
	MANCOZEB	Fungicide
	METIRAM	Fungicide
	THIRAM	Fungicide
	ZINEB	Fungicide
	ZIRAM	Fungicide
	NABAM	Fungicide
	SODIUM DIMETHYLDITHIOCARBAMATE	Fungicide
	DESMEDIPHAM	Herbicide
	PHENMEDIPHAM	Herbicide
	DISODIUM CYANODITHIOMIDOCARBONATE	Antimicrobial
	POTASSIUM N-METHYLDITHIOCARBAMATE	Antimicrobial
	POTASSIUM N-HYDROXYMETHYL-N-METHYLDITHIOCARBAMATE	Preservative
	POTASSIUM DIMETHYLDITHIOCARBAMATE	Preservative
	DAZOMET	Soil Fumigant
	METAM	Soil Fumigant
Fatty Acids	TALLOW FATTY ACID AMINE ETHOXYLATE	Adjuvant
	TALL OIL FATTY ACIDS	Adjuvant
	SODIUM DODECYLBENZENESULFONATE	Disinfectant
	FATTY ACID	Herbicide
	SOAP (HERBICIDAL)	Herbicide

Chemical Group	Active Ingredient Name	Type of Use
	SOAP	Insecticide
	SAFER'S INSECTICIDAL SOAP	Insecticide
	POLY[OXYETHYLENE(DIMETHYLIMINIO)ETHYLENE(DIMETHYLIMINIO)ETHYLENE DICHLORIDE]	Antimicrobial
	POLY[HYDROXYETHYLENE(DIMETHYLIMINIO)ETHYLENE(DIMETHYLIMINIO)METHYLENE DICHLORIDE]	Antimicrobial
Halogenated Hydrocarbons	METHYL BROMIDE	Insecticide
	1,4-BIS(BROMOACETOXY)-2-BUTENE	Antimicrobial
	B-BROMO-B-NITROSTYRENE	Antimicrobial
	1,2-DIBROMO-2,4-DICYANOBUTANE	Preservative
	DIODOFON	Preservative
Hydrocarbons	PETROLEUM HYDROCARBON BLEND	Adjuvant
	ASPHALT SOLIDS	Fungicide
	NAPHTHALENE	Insecticide
	MUSCALURE	Insecticide
	POLYMERIZED BUTENES	Vertebrate
Indanediones	CHLOROPHACINONE	Vertebrate
	DIPHACINONE PRESENT IN FREE FORM OR AS SODIUM SALT	Vertebrate
	PINDONE PRESENT IN FREE FORM OR AS SODIUM SALT	Vertebrate
Inorganic Coppers	COPPER AS ELEMENTAL, PRESENT AS TRIBASIC COPPER SULPHATE	Fungicide
	COPPER THIOCYANATE (ALSO EXPRSSED IN TERMS OF COPPER AS ELEMENTAL)	Fungicide
	COPPER AS ELEMENTAL, PRESENT AS COPPER SULPHATE	Fungicide
	COPPER AS ELEMENTAL, PRESENT AS COPPER OXYCHLORIDE	Fungicide
	COPPER AS ELEMENTAL, PRESENT AS CUPRIC HYDROXIDE	Fungicide
	COPPER AS ELEMENTAL, PRESENT AS COPPER TRIETHANOLAMINE COMPLEX	Herbicide
	COPPER POWDER, METALLIC	Preservative
	CUPROUS OXIDE (ALSO EXPRESSED IN TERMS OF COPPER AS ELEMENTAL)	Preservative
	COPPER AS ELEMENTAL, PRESENT AS COPPER NAPHTHENATE	Wood Preservative
	CUPRIC OXIDE	Wood Preservative
	COPPER 8-QUINOLINOLATE	Wood Preservative
Inorganic Zincs	ZINC OXIDE	Disinfectant
	ZINC BORATE	Preservative
	ZINC PHOSPHIDE	Vertebrate
	ZINC	Wood Preservative
	ZINC AS ELEMENTAL, PRESENT AS ZINC NAPHTHENATE	Wood Preservative
Inorganics, Other	AMMONIUM SULPHATE	Adjuvant
	DIAMMONIUM PHOSPHATE	Adjuvant
	CALCIUM HYPOCHLORITE	Disinfectant
	HYDROCHLORIC ACID	Disinfectant
	POTASSIUM MONOPERSULPHATE	Disinfectant
	PHOSPHORIC ACID	Disinfectant

Chemical Group	Active Ingredient Name	Type of Use
	POTASSIUM HYDROXIDE	Disinfectant
	SODIUM BROMIDE	Disinfectant
	SODIUM CARBONATE	Disinfectant
	SULPHURIC ACID	Disinfectant
	TETRAPOTASSIUM PYROPHOSPHATE	Disinfectant
	SULPHUR (FUNGICIDE)	Fungicide
	I IME SULPHUR OR CALCIUM POLYSULPHIDE	Fungicide
	MERCURIC CHLORIDE	Fungicide
	MERCUROUS CHLORIDE	Fungicide
	CHLORINE DIOXIDE FROM SODIUM CHLORITE	Fungicide
	SODIUM HYPOCHLORITE	Fungicide
	AMMONIUM SULPHAMATE	Herbicide
	FERROUS SULFATE	Herbicide
	SODIUM CHLORATE	Herbicide
	SODIUM METABORATE OCTAHYDRATE	Herbicide
	SODIUM METABORATE TETRAHYDRATE	Herbicide
	ALUMINUM PHOSPHIDE	Insecticide
	BORAX, ANHYDROUS	Insecticide
	BORAX PENTAHYDRATE	Insecticide
	BORAX	Insecticide
	BORACIC ACID	Insecticide
	CARBON DIOXIDE	Insecticide
	HYDROGEN PEROXIDE	Insecticide
	SODIUM FLUORIDE	Insecticide
	SODIUM FLUOSILICATE (OR SODIUM SILICOFLUORIDE)	Insecticide
	SILICA AEROGEL	Insecticide
	SILICON DIOXIDE SALT WATER FOSSILS	Insecticide
	SULPHUR (INSECTICIDE)	Insecticide
	IODINE	Antimicrobial
	LITHIUM HYPOCHLORITE	Antimicrobial
	BARIUM METABORATE MONOHYDRATE	Preservative
	AMMONIA	Vertebrate
	HYDROGEN CYANIDE	Vertebrate
	SULPHUR (VERTEBRATE CONTROL)	Vertebrate
	ARSENIC PENTOXIDE	Wood Preservative
	DISODIUM OCTABORATE TETRAHYDRATE	Wood Preservative
	CHROMIC ACID	Wood Preservative
	POTASSIUM DICHROMATE	Wood Preservative
Microbials (Other than Bt)	AGROBACTERIUM RADIOBACTER	Fungicide
	COLLETOTRICHUM GLOEOSPORIOIDES f.sp. MALVAE	Herbicide
	NUCLEAR POLYHEDROSIS VIRUS OF THE GYPSY MOTH	Insecticide
	NUCLEAR POLYHEDROSIS VIRUS OF RED-HEADED PINE SAWFLY	Insecticide
	NUCLEAR POLYHEDROSIS VIRUS OF DOUGLAS-FIR TUSSOCK MOTH	Insecticide
Miscellaneous (Non-Classified)	N-ALKYL DIETHANOLAMINE	Adjuvant
	N-ALKYL POLYETHOXYETHANOL	Adjuvant
	POLYACRYLIC POLYMER	Adjuvant
	POLYOXYALKYLATED ALKYL PHOSPHATE ESTER	Adjuvant

Chemical Group	Active Ingredient Name	Type of Use
	POLYVINYL POLYMER	Adjuvant
	POLYOXYETHYLENE (20) SORBITAN MONOLAURATE	Adjuvant
	1-(ALKYL-AMINO)-3-AMINOPROPANE HYDROCHLORIDE (COMPONENT OF AMPHO 443-31)	Disinfectant
	1-(ALKYL-AMINO)-3-CARBOXYMETHYLAMINOPROPANE (COMPONENT OF AMPHO 443-31)	Disinfectant
	BUTOXYPOLYPROPOXYPOLYETHOXYETHANOL - IODINE COMPLEX	Disinfectant
	COAL TAR OILS	Disinfectant
	MIXTURE OF 3 COMPOUNDS: BCD + DDH + DDM	Disinfectant
	MIXTURE OF 2 COMPOUNDS: DDH + DDM	Disinfectant
	1,3-DICHLORO-5-ETHYL-5 METHYLHYDANTOIN	Disinfectant
	DIPROPYLENE GLYCOL	Disinfectant
	PARAFORMALDEHYDE	Disinfectant
	POLYETHOXYPOLYPROPOXYPOLYETHOXYETHANOL-IODINE COMPLEX	Disinfectant
	ALKYL MORPHOLINIUM ETHOSULPHATE (1% C14, 22% C16, 77% C18)	Disinfectant
	SODIUM PARA-TERTIARY AMYLPHENATE	Disinfectant
	SODIUM HYDROXIDE	Disinfectant
	SODIUM LAURYL SULFATE	Disinfectant
	CYPRODINIL	Fungicide
	DICHLOFLUANID	Fungicide
	ETHOXYQUIN	Fungicide
	FORMALDEHYDE	Fungicide
	ETHOFUMESATE	Herbicide
	ACROLEIN	Herbicide
	BENAZOLIN PRESENT AS DIMETHYLAMINE SALT	Herbicide
	WATER SOLUBLE DYES	Herbicide
	PROPARGITE	Insecticide
	METHOPRENE	Insecticide
	STYRENE BUTADIENE COPOLYMER RUBBER	Insecticide
	CHLORDECONE	Insecticide
	NATURAL GUM RESINS	Insecticide
	KINOPRENE	Insecticide
	B-BUTOXY-B'-THIOCYANODIETHYL ETHER	Insecticide
	METALDEHYDE	Insecticide
	METHYL ISOTHIOCYANATE	Insecticide
	SODIUM SALT OF N-(3,4-DICHLOROPHENYL)-N'-2 (2-SULFO-4-CHLOROPHENOXY)-5-CHLOROPHENYL UREA	Insecticide
	PIPERONYL BUTOXIDE	Insecticide
	PHEROMONE: CODLING MOTH	Insecticide
	PHEROMONE: GRAPE BERRY MOTH	Insecticide
	SULFOXIDE PLUS RELATED ACTIVE COMPOUNDS	Insecticide
	Z-11-TETRADECENYL ACETATE (OR: CIS-11-TETRADECENYL ACETATE)	Insecticide
	BEDOUKIAN TPW TECHNICAL PHEROMONE	Insecticide
	N-ALKYL-1,3 PROPANEDIAMINE MONOBENZOATE	Antimicrobial
	1-ALKYL (C8-C18)-1,3-PROPANEDIAMINE ACETATE	Antimicrobial
	1-ALKYL C6-C18 1,3-PROPANE DIAMINE	Antimicrobial

Chemical Group	Active Ingredient Name	Type of Use
	DEHYDROABIETYLAMINE ACETATE	Antimicrobial
	DEHYDROABIETYLAMINE ETHYLENE OXIDE	Antimicrobial
	GLUTARALDEHYDE	Antimicrobial
	METHYLENE BIS(THIOCYANATE)	Antimicrobial
	N-[A-(1-NITROETHYL)BENZYL]ETHYLENEDIAMINE, PRESENT AS POTASSIUM SALT	Antimicrobial
	OXYDIETHYLENE BIS(ALKYL DIMETHYL AMMONIUM CHLORIDE)	Antimicrobial
	DICHLORFLURECOL-METHYL	Plant Growth Regulator
	FLURECOL-METHYL	Plant Growth Regulator
	BENZYL BROMOACETATE	Preservative
	2,2-OXYBIS(4,4,6-TRIMETHYL-1,3,2-DIOXABORINANE)	Preservative
	2,2'-DITHIOBISBENZAMIDE	Preservative
	DIPHENYLSTIBINE 2-ETHYLHEXOATE	Preservative
	OXIRANE DERIVATIVES (50% MINIMUM)	Preservative
	2,2'-(1-METHYLTRIMETHYLENEDIOXY)BIS-(4-METHYL-1,3,2-DIOXABORINANE)	Preservative
	ETHYLENE OXIDE	Soil Fumigant
	DIMETHYL ALKYL AMINE	Vertebrate
	PUTRESCENT WHOLE EGG SOLIDS	Vertebrate
	METHYL NONYL KETONE	Vertebrate
Nitro Derivatives	DICHLORAN	Fungicide
	DINOCAP PLUS RELATED ACTIVE COMPOUNDS	Fungicide
	OXYFLUORFEN	Herbicide
	DINOSEB PRESENT IN FREE FORM	Herbicide
	ETHALFLURALIN	Herbicide
	PENDIMETHALIN	Herbicide
	TRIFLURALIN	Herbicide
	BROMETHALIN	Vertebrate
	@-@,@-TRIFLUORO-4-NITRO-M-CRESOL	Vertebrate
	DINITROPHENOL	Wood Preservative
Oils, Mineral and Vegetable	PARAFFIN BASE MINERAL OIL (ADJUVANT)	Adjuvant
	MINERAL OIL (HERBICIDAL OR PLANT GROWTH REGULATOR)	Adjuvant
	PARAFFIN BASE PETROLEUM OIL	Adjuvant
	VEGETABLE OIL	Adjuvant
	SURFACTANT MIXTURE	Adjuvant
	SURFACTANT BLEND	Adjuvant
	PINE OIL	Disinfectant
	XYLENOLS	Disinfectant
	CITRONELLA TERPENE	Insecticide
	OIL OF CITRONELLA	Insecticide
	ARTIFICIAL ESSENTIAL OIL BLEND -- SEE CHEMISTRY FILE FOR LIST OF OILS	Insecticide
	OIL OF LAVENDER	Insecticide
	MINERAL OIL (INSECTICIDAL OR ADJUVANT)	Insecticide
	OIL OF LEMONGRASS	Insecticide

Chemical Group	Active Ingredient Name	Type of Use
	OLEORESIN CAPSICUM (OF WHICH PRINCIPAL COMPONENT IS CAPSAICIN)	Vertebrate
	PIPERINE	Vertebrate
	OIL OF BLACK PEPPER	Vertebrate
	CEDAR LEAF OIL	Vertebrate
	MUSTARD OIL	Vertebrate
	BLEND OF OILS: OF LEMONGRASS, OF CITRONELLA, OF ORANGE, OF BERGAMOT; GERANIOL, IONONE ALPHA, METHYL SALICYLATE AND ALLYLISOTHIOCYANATE	Vertebrate
Organic Acids	ACETIC ACID	Disinfectant
	CITRIC ACID	Disinfectant
	TCA PRESENT AS SODIUM SALT	Herbicide
	DAMINOZIDE	Plant Growth Regulator
	GIBBERELLIC ACID	Plant Growth Regulator
	NAPHTHALENE ACETIC ACID (PRESENT AS ETHYL ESTER, SODIUM SALT, OR AS AMMONIUM SALT)	Plant Growth Regulator
	PIMARICIN	Preservative
	SODIUM MONOFLUOROACETATE	Vertebrate
Organochlorines	QUINTOZENE	Fungicide
	CHLORONEB	Fungicide
	DICHLONE	Fungicide
	DIENOCHLOR	Insecticide
	ENDOSULFAN	Insecticide
	GAMMA-BHC FROM LINDANE	Insecticide
	DICOFOL	Insecticide
	METHOXYCHLOR	Insecticide
	PARADICHLOROBENZENE	Insecticide
	BIS(TRICHLOROMETHYL)SULFONE	Antimicrobial
	CHLORFLURECOL-METHYL	Plant Growth Regulator
	CHLOROPICRIN	Soil Fumigant
	1,3-DICHLOROPROPENE	Soil Fumigant
Organometallics	TRIBUTYLTIN OXIDE	Fungicide
	TRI-N-BUTYLTIN CHLORIDE	Fungicide
	TRI-N-BUTYLTIN FLUORIDE	Fungicide
	TRI-N-BUTYLTIN MALEATE	Fungicide
	TRI-N-BUTYLTIN METHACRYLATE	Fungicide
	DI(PHENYLMERCURIC)DODECENYL SUCCINATE	Fungicide
	MERCURY AS ELEMENTAL, PRESENT AS PHENYLMERCURIC SALTS OF DODECENYL SUCCINIC AND TALL OIL FATTY ACIDS	Fungicide
	PHENYLMERCURIC ACETATE	Fungicide
	N-PHENYL MERCURY 2-ETHYLHEXYL MALEATE	Fungicide
	PHENYLMERCURIC OLEATE	Fungicide
	ARSENIC AS ELEMENTAL, PRESENT AS DODECYL AND OCTYL AMMONIUM METHYL ARSENATES	Herbicide

Chemical Group	Active Ingredient Name	Type of Use
	ARSENIC AS ELEMENTAL, PRESENT AS MONOSODIUM METHANE ARSONATE	Herbicide
	FENBUTATIN OXIDE	Insecticide
	10,10'-OXYBIS(PHENOXARSINE)	Preservative
Organophosphorous	FOSETYL-AL	Fungicide
	PYRAZOPHOS	Fungicide
	BENSULIDE	Herbicide
	TEMEPHOS	Insecticide
	ACEPHATE	Insecticide
	AZAMETHIPHOS	Insecticide
	CHLORFENVINPHOS	Insecticide
	COUMAPHOS	Insecticide
	TERBUFOS	Insecticide
	DIMETHOATE	Insecticide
	DISULFOTON	Insecticide
	CHLORPYRIFOS	Insecticide
	DICHLORVOS PLUS RELATED ACTIVE COMPOUNDS	Insecticide
	ETHION	Insecticide
	FENSULFOTHION	Insecticide
	FENITROTHION	Insecticide
	FENTHION	Insecticide
	TETRACHLORVINPHOS	Insecticide
	AZINPHOS-METHYL	Insecticide
	MALATHION	Insecticide
	METHIDATHION	Insecticide
	METHAMIDOPHOS	Insecticide
	NALED	Insecticide
	OXYDEMETON-METHYL	Insecticide
	PHORATE	Insecticide
	PHOSALONE	Insecticide
	PHOSMET	Insecticide
	PARATHION	Insecticide
	SULFOTEP PLUS RELATED ACTIVE COMPOUNDS	Insecticide
	DIAZINON	Insecticide
	CROTOXYPHOS	Insecticide
	IODOFENPHOS	Insecticide
	PROPETAMPHOS	Insecticide
	DIMETHOXANE	Antimicrobial
Phenols	COAL TAR ACIDS	Disinfectant
	O-PHENYLPHENOL	Disinfectant
	ORTHO-PHENYLPHENOL (POTASSIUM SALT)	Disinfectant
	SODIUM O-PHENYLPHENATE	Disinfectant
	P-TERT AMYL PHENOL	Disinfectant
	M-CRESOL	Fungicide
	2,4-XYLENOL (OR 2,4-DIMETHYLPHENOL)	Fungicide
	CRESYLIC ACID (OR: PHENOLIC HOMOLOGUES; A MIXTURE OF CRESOLS, XYLENOLS, ETHYL PHENOLS AND HIGHER MOLECULAR WEIGHT PHENOLS)	Insecticide
	2-BROMO-4'-HYDROXYACETOPHENONE	Antimicrobial
	2-(P-HYDROXYPHENYL)GLYOXYLOHYDROXYMOYL	Antimicrobial

Chemical Group	Active Ingredient Name	Type of Use
	CHLORIDE	
	CREOSOTE	Wood Preservative
Phenoxy Acids	DICHLORPROP PRESENT AS DIMETHYLAMINE SALT	Herbicide
	DICHLORPROP PRESENT AS BUTOXYETHYL ESTER OR AS ISOOCTYL ESTER	Herbicide
	2,4-DB PRESENT AS MIXED BUTYL ESTERS OR AS ISOOCTYL ESTERS	Herbicide
	2,4-D PRESENT AS ACID	Herbicide
	2,4-D PRESENT AS AMINE SALTS (DIMETHYLAMINE SALT, DIETHANOLAMINE SALT, OR OTHER AMINE SALTS)	Herbicide
	2,4-D PRESENT AS LOW VOLATILE ESTERS	Herbicide
	2,4-D PRESENT AS SODIUM SALT	Herbicide
	MCPA PRESENT AS ACID	Herbicide
	MCPA PRESENT AS AMINE SALTS (diethanolamine, dimethylamine, or mixed amines)	Herbicide
	MCPA PRESENT AS ESTERS	Herbicide
	MCPA PRESENT AS POTASSIUM SALT OR AS SODIUM SALT	Herbicide
	MCPB PRESENT AS SODIUM SALT	Herbicide
	MCPB PRESENT AS ISOMER SPECIFIC	Herbicide
	MECOPROP (D-ISOMER) PRESENT AS POTASSIUM SALT	Herbicide
	MECOPROP (D-ISOMER) PRESENT AS AMINE SALTS	Herbicide
	MECOPROP (D-ISOMER) PRESENT AS ACID	Herbicide
	MECOPROP D-ISOMER	Herbicide
	4-CPA	Plant Growth Regulator
Phosphonic Acids, Phosphinic Acids	GLUFOSINATE AMMONIUM	Herbicide
	ISOPROPYLAMINE SALT OF GLYPHOSATE	Herbicide
	MONO-AMMONIUM SALT OF GLYPHOSATE	Herbicide
	GLYPHOSATE ACID	Herbicide
	TRIMETHYLSULFONIUM SALT OF GLYPHOSATE	Herbicide
	FOSAMINE AMMONIUM	Herbicide
	FONOFOS	Insecticide
	TRICHLORFON	Insecticide
	ETHEPHON	Plant Growth Regulator
Phthalic Acids	CAPTAN	Fungicide
	FOLPET	Fungicide
	NAPTALAM PRESENT AS ACID OR AS SODIUM SALT	Herbicide
	CHLORTHAL PRESENT AS ACID OR AS DIMETHYL ESTER	Herbicide
	ENDOTHALL PRESENT AS DIPOTASSIUM SALT	Herbicide
	DIMETHYL PHTHALATE	Insecticide
	N-OCTYL BICYCLOHEPTENE DICARBOXIMIDE	Insecticide
Pyrethroids, Pyrethrins	D-CIS, TRANS ALLETHRIN	Insecticide
	D-TRANS ALLETHRIN	Insecticide
	ALLETHRIN	Insecticide
	CYFLUTHRIN	Insecticide
	CYPERMETHRIN	Insecticide
	DELTAMETHRIN	Insecticide

Chemical Group	Active Ingredient Name	Type of Use
	FENVALERATE	Insecticide
	FLUCYTHRINATE	Insecticide
	FLUVALINATE	Insecticide
	TETRAMETHRIN PLUS RELATED ACTIVE COMPOUNDS	Insecticide
	PERMETHRIN	Insecticide
	PYRETHRINS	Insecticide
	RESMETHRIN	Insecticide
	TEFLUTHRIN	Insecticide
	CYHALOTHRIN-LAMDA (PROPOSED)	Insecticide
	CYPHENOTHRIN	Insecticide
	D-PHENOTHRIN	Insecticide
	TRALOMETHRIN	Insecticide
Pyridines	SODIUM OMADINE	Disinfectant
	DITHIOPYR	Herbicide
	FLUROXYPYR 1-METHYLHEPTYL ESTER	Herbicide
	NICOTINE PRESENT AS ALKALOID OR AS SULPHATE	Insecticide
	DI-N-PROPYL ISOCINCHOMERONATE	Insecticide
	PYRIPROXYFEN	Insecticide
	4-AMINOPYRIDINE	Vertebrate
Sulfonylureas, Uracils	CHLORIMURON-ETHYL	Herbicide
	2-CHLORO-N-[(4-METHOXY-6-METHYL-1,3,5-TRIAZIN-2 YL)AMINOCARBONYL]BENZENE SULFONAMIDE (Chlorsulfuron)	Herbicide
	RIMSULFURON	Herbicide
	ETHAMETSULFURON-METHYL	Herbicide
	METSULFURON-METHYL	Herbicide
	2-[[N[4-METHOXY-6-METHYL-1,3,5-TRIAZINE-2-YL]-N-METHYLAMINOCARBONYL]AMINOSULFONYL]-METHYL ESTER BENZOIC ACID (Tribenuron methyl)	Herbicide
	THIFENSULFURON METHYL	Herbicide
	NICOSULFURON	Herbicide
	PROSULFURON	Herbicide
	TRIASULFURON	Herbicide
	BROMACIL PRESENT IN FREE FORM, AS DIMETHYLAMINE SALT, OR AS LITHIUM SALT	Herbicide
	TERBACIL	Herbicide
Thiocarbamates	EPTC	Herbicide
	PEBULATE	Herbicide
	CYCLOATE	Herbicide
	BUTYLATE	Herbicide
	TRIALLATE	Herbicide
	VERNOLATE	Herbicide
Triazines, Triazinones, Tetrazines	POTASSIUM DICHLORO-S-TRIAZINETRIONE	Disinfectant
	SODIUM DICHLORO-S-TRIAZINETRIONE	Disinfectant
	ANILAZINE	Fungicide
	ATRAZINE PLUS RELATED ACTIVE TRIAZINES	Herbicide
	METRIBUZIN	Herbicide

Chemical Group	Active Ingredient Name	Type of Use
	CYANAZINE	Herbicide
	PROMETON PLUS RELATED ACTIVE TRIAZINES	Herbicide
	PROMETRYNE PLUS RELATED ACTIVE TRIAZINES	Herbicide
	SIMAZINE PLUS RELATED ACTIVE TRIAZINES	Herbicide
	HEXAZINONE	Herbicide
	CLOFENTEZINE	Insecticide
	CYROMAZINE	Insecticide
	TRICHLORO-S-TRIAZINETRIONE	Antimicrobial
	HEXAHYDRO-1,3,5-TRIETHYL-S-TRIAZINE	Preservative
	HEXAHYDRO-1,3,5-TRIS(2-HYDROXYETHYL)-S-TRIAZINE	Preservative
Urea Derivatives	DIFLUBENZURON	Adjuvant
	DIURON	Herbicide
	LINURON	Herbicide
	MONOLINURON	Herbicide
	METOBROMURON	Herbicide
	SIDURON	Herbicide
	TEBUTHIURON	Herbicide
	MONURON	Herbicide
	HALANE	Insecticide
	1-BROMO-3-CHLORO-5,5-DIMETHYLHYDANTOIN	Antimicrobial

Appendix 2. Herbicide Groups Based on Sites of Action for Resistance Management

Resistance Group and Site of Action	Active Ingredient
1. (Acetyl CoA carboxylase (ACCase) inhibitors)	Clodinafop-propargyl Diclofop-methyl Fenoxaprop-ethyl Fenoxaprop-p-ethyl Fluazifop-p-butyl Fluazifop-butyl Quizalofop-ethyl Quizalofop-p-ethyl Clethodim Sethoxydim Tralkoxydim
2 (Acetolactate synthase/aceto-hydroxyacid synthase (ALS/AHAS) inhibitors)	Chlorimuron Chlorsulfuron Ethamethsulfuron-methyl Metsulfuron-methyl Nicosulfuron Prosulfuron Rimsulfuron Sulfosulfuron Thifensulfuron-methyl Triasulfuron Tribenuron-methyl Triflusulfuron-methyl Imazmethabenz Imazamox Imazapyr Imazamethapyr Flumetsulam
3 (Microtubule assembly inhibitors)	Ethalfluralin Pendimethalin Trifluraliln Dithiopyr Chlorthal-dimethyl (DCPA)
4 (Synthetic auxins)	2,4-D (acid, amines, esters, sodium & potassium salts) 2,4-DB (isomer specific, sodium salt) Dichlorprop (2,4-DP) MCPA (acid, amines, esters, sodium & potassium salts) MCPB Mecoprop (MCPP)(acid, amine salt)

Resistance Group and Site of Action	Active Ingredient
	Dicamba Clopyralid Fluroxypyr Picloram (acid, ester or amine & potassium salts) Triclopyr Quinclorac Diflufenzopyr
5 (Photosynthesis inhibitor at photosystem (PS) II Site A)	Atrazine Cyanazine Prometon Prometryn Simazine Hexazinone Metribuzin Bromacil Terbacil Pyrazon Desmedipham Phenmedipham
6 (Similar to Group 5, but different binding behavior)	Bromoxynil Bentazon Pyridate
7 (Photsynthesis inhibitors at PS II Site B)	Diuron Linuron Metobromuron Monolinuron Siduron Teburthiuron Propanil
8 (Lipid synthesis inhibitors – not ACCase inhibition)	Butylate Cycloate EPTC Pebulate Triallate Vernolate Bensulide Difenzoquat
9 (EPSP* synthase inhibitors)	Glyphosate (acid, monoammonium, isopropylamine or trimethylsulfonium salt)
10 (Glutamine synthetase inhibitors)	Glufosinate ammonium

Resistance Group and Site of Action	Active Ingredient
11 (Bleaching: Carotenoid biosynthesis inhibitors)	Amitrole
14 (Protoporphyrinogen oxidase (PPO) inhibitors)	Acifluorfen Fomesafen Oxyfluorfen Oxadiazon
15 (Unknown)	Metolachlor s-metolachlor Propyzamide Dimethenamid Napropamide
16 (Unknown)	Ethofumesate
17 (Unknown)	Arsenic (MSMA)
19 (Indoleacetic acid action inhibitors)	Naptalam
20 (Inhibits cell wall synthesis Site A)	
22 (Photo systems I-electron diverters)	Diquat Paraquat
23 (Mitosis inhibitors)	Chlorpropham
25 (Unknown)	Flamprop-methyl
Non classified Herbicides	Acrolein Benazolin Chloramben Copper as elemental Ferrous Sulfate Endothall Monuron Sodium Chlorate Sodium Metaborate Tetrahydrate

*Enolpyruvylshikimate-3-phosphate